Serfoji Rajah 1827

A

COMPLETE TREATISE

ON

ELECTRICITY,

IN

THEORY AND PRACTICE;

WITH

ORIGINAL EXPERIMENTS.

By TIBERIUS CAVALLO, F.R.S.

THE FOURTH EDITION,

IN THREE VOLUMES;

Containing the PRACTICE of MEDICAL ELECTRICITY, besides other ADDITIONS and ALTERATIONS.

THE THIRD VOLUME IS ENTIRELY NEW,

And contains the DISCOVERIES *and* IMPROVEMENTS *made since the Third Edition.*

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A COMPLETE

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ON

ELECTRICITY.

PART IV.

NEW EXPERIMENTS IN ELECTRICITY.

THE laws of Electricity, together with the experiments neceſſary for their demonſtration, having already been deſcribed, in as compendious a manner as could be done without obſcurity, I ſhall, in the laſt Part of this Work, relate ſuch new experiments and obſervations as I have made at different times, principally with a view to diſcover, if poſſible, the unknown cauſe of ſeveral electrical phenomena, eſpecially thoſe relative to atmoſpherical Electricity.

The first instrument that I made use of to observe the Electricity of the atmosphere, was an electrical kite, which I had constructed, not with a view to observe the Electricity of the air; for this, I thought, was very weak, and seldom to be observed; but as an instrument which could be occasionally used in time of a thunder-storm, in order to observe the Electricity of the clouds. The kite, however, being just finished, together with its string, which contained a brass wire through its whole length, I raised it on the 31st of August 1775, at seven of the clock in the afternoon, the weather being a little cloudy, and the wind just sufficient for the purpose. The extremity of the string being insulated; I applied my fingers to it; which, contrary to my expectation, drew very vivid and pungent sparks: I charged a coated phial at the string several times, but I did not then observe the quality of the Electricity. This successful experiment induced me to raise the kite very often, and to keep it up for several hours together; thinking that if any periodical Electricity, or any change of its quality, took place in the atmosphere, it might very probably be

 discovered

diſcovered by this inſtrument. In the following two Chapters I ſhall deſcribe the conſtruction of the electrical kite, with its appurtenances; and ſhall tranſcribe the moſt remarkable part of my journal relative to the kite; *i. e.* deſcribing ſuch experiments only as are moſt remarkable, and do not happen very commonly; for although I have uſed my kite ſometimes ten, and more times in a week, and at any hour of the day or night, yet as the greateſt part of thoſe experiments are only of uſe to confirm a few laws of atmoſpherical Electricity, I ſhall omit their particular detail, and ſhall only ſubjoin thoſe laws at the end of the ſecond chapter.

CHAP. I.

The Conſtruction of the electrical Kite, and other Inſtruments uſed with it.

THE firſt electrical kite that I conſtructed, was ſeven feet high; and it was made of paper, with a ſtick or ſtraiter, and a cane-bow, like the kites commonly uſed by ſchool-boys. On the upper part of the ſtraiter I fixed an iron ſpike, projecting about a foot above the kite, which I then thought was abſolutely neceſſary to collect the Electricity; and I covered the paper of the kite with turpentine, in order to defend it from the rain. The kite, perfect as I thought it to be in its conſtruction, and fit for the experiments for which it was intended, ſoon manifeſted its imperfections, and after having been raiſed a few times, it became quite unfit for farther uſe; it being ſo large, and conſequently heavy, that it could not be uſed, except when the wind was ſtrong; and then, after much trouble

in raiſing and drawing it in, it often receiv-ed ſome damage: which ſoon obliged me to conſtruct other kites upon a different plan, in order to aſcertain which method would anſwer the beſt for my purpoſe. I gradually leſſened their ſize, and varied their form, till I obſerved, upon trial, that a com-mon ſchool-boy's kite was as good an electrial kite as mine. In conſequence of which I conſtructed my kites in the moſt ſimple manner, and in nothing different from the children's kites, except that I co-vered them with varniſh, or with well-boiled linſeed-oil, in order to defend them from the rain; and I covered the back part of the ſtraiter with tin-foil, which, how-ever, has not the leaſt power to increaſe its Electricity. I alſo furniſh the upper extre-mity of the ſtraiter with a ſlender wire pointed, which, in time of a thunder-ſtorm, may perhaps draw the Electricity from the clouds ſomewhat more effectually; but in general, I find, as it will appear in the ac-count of the experiments, that it does not in the leaſt affect the Electricity at the ſtring. The kites that I have generally uſed are about four feet high, and little above two

feet wide. This ſize, I find, is the moſt convenient, becauſe it renders them eaſy to be managed, and, at the ſame time, they can draw a ſufficient quantity of ſtring. As for ſilk or linen kites, they require a good deal of wind to be raiſed; and then they are not ſo cheap, nor ſo eaſy to be made, as paper kites are. The ſtring ſometimes breaks, and the kite is loſt, or broken; for which reaſon theſe kites ſhould be made as cheap and as ſimple as poſſible.

The ſtring is the moſt material part of this apparatus; for the Electricity produced is more or leſs, according as the ſtring is a better or a worſe Conductor. The ſtring which I made for my large kite, conſiſted of two threads of common twine, twiſted together with a braſs wire between the ſtrands. This ſtring ſerved very well for two or three trials; but, on examination, I ſoon found, that the wire in it was broken in many places, and it was continually ſnapping; the metallic continuation, therefore, being ſo often interrupted, the ſtring became ſoon ſo bad, that it acted nothing better than common twine without a wire.

I at-

I attempted to mend it, by joining the broken pieces of wire, and working into the twine another wire, which proved a very laborious work; but the remedy had very little effect, the wire breaking again after the first trial; which determined me to adopt other methods: and, after several experiments, I found that the best string was one, which I made by twisting a copper thread * with two very thin threads of twine. Strings like this I have used for the greatest part of my experiments with the kite, and I find them to be exceedingly useful, and fit for the purpose. Silver or gold thread would do much better to twist with the twine, because they are much thinner than copper thread, and, in consequence, the string would be much lighter; but, at the same time, it is to be considered, that gold or silver thread is much dearer than copper thread.

I have attempted to render the twine a good Conductor of Electricity, by cover-

* I mean such a thread of copper as is used for trimmings, &c. in imitation of gold threads; which are nothing more than silk, or linen threads, covered with a thin lamina of copper.

ing it with conducting ſubſtances; as lamp-black, powder of charcoal, very fine emery, and other ſubſtances, mixing them with diluted gum-water; but this method improves the ſtring very little, and for a very ſhort time; for the ſaid conducting ſubſtances are ſoon rubbed off the twine. Mr. NAIRNE informed me, that he had uſed to ſoak the ſtring of his electrical kite in a ſtrong ſolution of ſalt, which rendered it a good Conductor, ſo far as it attracted the moiſture of the air. In conſequence of this information, I ſoaked in ſalt-water a long piece of twine, and, by raiſing a kite with it, I found that it conducted the Electricity pretty well; but I thought it much inferior to the above-deſcribed ſtring with the copper thread: beſides, the ſalted ſtring in wet weather not only leaves part of the ſalt upon the hands of the operator, and, in conſequence, renders them unfit to manage the reſt of the apparatus, but it marks a white ſpot wherever it touches the clothes.

In raiſing the kite when the weather is very cloudy and rainy, in which time there

there is fear of meeting with great quantity of Electricity, I generally use to hang upon the string A B, fig. 9. Plate IV. the hook of a chain C, the other extremity of which falls upon the ground. Sometimes I use another caution besides, which is, to stand upon an insulating stool; in which situation I think, that if any great quantity of Electricity, suddenly discharged by the clouds, strikes the kite, it cannot affect much my person. As to insulated reels, and such-like instruments, that some gentlemen have used to raise the kite, without danger of receiving any shock; fit for the purpose as they may appear to be in theory, they are yet very inconvenient to be managed. Except the kite be raised in time of a thunder-storm, there is no great danger for the operator to receive any shock. Although I have raised my electrical kite hundreds of times without any caution whatever, I have very seldom received a few exceedingly slight shocks in my arms. In time of a thunder-storm, if the kite has not been raised before, I would not advise a person to raise it while the stormy clouds are just overhead; the danger in such time

being

being very great, even with the precautions above-mentioned: at that time, without raising the kite, the Electricity of the clouds may be observed by a cork-ball electrometer held in the hand in an open place; or, if it rains, by my electrometer for the rain; which will be described hereafter.

When the kite has been raised, I generally introduce the string through a window in a room of the house, and fasten it to a strong silk lace, the extremity of which is generally tied to a heavy chair in the room. In fig. 8. of Plate III. AB represents part of the string of the kite which comes within the room; C represents the silk lace; DE, a small prime Conductor, which, by means of a small wire, is connected with the string of the kite; and F represents the quadrant electrometer, fixed upon a stand of glass covered with sealing-wax, which I used to put near the prime Conductor, rather than to fix it in a hole upon the Conductor, because the string AB sometimes shakes so as to pull the prime Conductor down; in which case the quadrant electrometer re-

mains

mains safe upon the table: otherwise it would be broken, as I have often experienced before I thought of this method. G represents a glass tube, about eighteen inches long, with a knobbed wire cemented to its extremity; with which instrument I use to observe the quality of the Electricity, when the Electricity of the kite is so strong that I think it not safe to come very near the string. The method is as follows:—I hold the instrument by that extremity of the glass tube which is the farthest from the wire, and touch the string of the kite with the knob of its wire, which, being insulated, acquires a small quantity of Electricity from it; which is sufficient to ascertain its quality when the knob of the instrument is brought near an electrified electrometer.

Sometimes, when I raise the kite in the night-time, out of the house, and where I have not the convenience of observing the quality of its Electricity by the attraction and repulsion, or even by the appearance of the electric light, I make use of a coated phial, which I can charge at the string, and, when charg-

ed,

ed, put it into my pocket; wherein it will keep charged even for ſeveral hours *. By making uſe of this inſtrument, I am obliged to keep the kite up no longer than is neceſſary to charge the phial, in order to obſerve the quality of the Electricity in the atmoſphere; for after the kite has been drawn in

* The conſtruction of this phial is as follows:—Beſides the coating of the inſide and outſide, that this phial has, like any other of the ſame kind, a glaſs tube, open at both ends, is cemented into its neck, and proceeds within the phial, having a ſmall wire faſtened to its lower extremity, which touches the inſide non-electric coating. The wire with the knob of this phial is cemented into another glaſs tube, which is nearly twice as long, and ſmaller than the tube cemented into the neck of the phial. The wire is cemented ſo, that only its knob projects out of one end, and a ſmall length of it out of the other end of the tube. If this piece with the wire be held by the middle of the glaſs tube, it may be put in or out of the tube which is in the neck of the phial, ſo as to touch the ſmall wire at the lower extremity of it, and that without diſcharging the phial, if it is charged. I have kept ſuch a phial charged for ſix weeks together; and probably it would keep much longer, if it were to be tried. The ingenious young Electrician may make uſe of ſuch a phial for ſeveral diverting purpoſes.—The piece of glaſs which ſerves to hold the wire by, is rather better to be fixed above than below the ball. In this caſe, the ball is perforated quite through, and the wire projects a ſhort way above it; to which the glaſs tube is cemented.

and

and brought home. I can then examine the Electricity of the inside of the phial, which is the same as that of the kite.

When the Electricity of the kite is very strong, I fix a chain, communicating with the ground, at about six inches distance from the string; which may carry off its Electricity, in case that this should increase so much as to put the by-standers in danger.

Besides the above-described apparatus, I have occasionally used some other instruments, which I have often varied, according as some particular experiments required; but, as they are of no great consequence, I shall omit to describe them. It is only necessary, before I enter into the narration of the principal experiments performed with the kite, to give an idea of the standard of my quadrant electrometer; which may, very probably, shew the same intensity of Electricity under a number of degrees different from the other instruments of the same kind. When the kite is flying, and the apparatus is disposed as in fig. 8. of

Plate

Plate III, I bring, under the extremity E of the prime Conductor, a little bran, held upon a tin plate, and obſerve, that when the index of the electrometer is at ten degrees, the prime Conductor begins to attract the bran at the diſtance of about three-fifths of an inch: when the index is at twenty degrees, the prime Conductor attracts the bran at the diſtance of about one inch and a quarter; when the index is at thirty degrees, the bran begins to be attracted at the diſtance of two inches and one-fifth. Theſe diſtances vary, as the weather changes its degree of dryneſs; but in froſty weather I obſerve them conſtantly as above.

CHAP. II.

Experiments performed with the electrical Kite.

SEptember the 2d, 1775. The weather being very cloudy, and actually raining, the kite was raiſed at eight o'clock P. M. with two hundred yards of ſtring, which had a braſs wire through its whole length. The wind was from the ſouth and very ſtrong. The Electricity at the ſtring was negative, and juſt ſufficient to charge a half-pint phial ſo as to give a ſhock ſenſible to the elbows. The kite, after being up for about one hour, fell to the ground, having its paper, which was not properly varniſhed, almoſt entirely torn off by the violence of the wind and rain.

September the 14th. The kite was raiſed with a ſtrong north wind at half paſt three P. M. The Electricity was poſitive, and

and pretty ſtrong, the index of the electrometer being generally about 20° *. The weather was rather cold, and very thick clouds were gradually approaching the zenith. The kite was pulled down at half paſt four P. M.

N. B. At night the aurora borealis was very ſtrong, and ſeveral flaſhes of lightning were ſeen near the horizon towards the north.

September the 23d. A ſmall kite was raiſed at half paſt ten o'clock in the morning, and it was kept up for eleven hours ſucceſſively, *viz.* till half paſt nine P. M. The ſtring, which was only a common twine, without a wire, was conſtantly electrified poſitively, although in a very ſmall degree. About nine o'clock the Electricity appeared ſtronger, ſo that a ſmall phial, charged at the ſtring, gave a pretty ſenſible ſhock. The weather was very clear, and warm; but in the night no aurora bo-

* The index of the electrometer in general riſes higher or falls lower, according as the kite comes nearer to, or goes farther from the zenith; the length of the ſtring remaining the ſame.

realis,

realis, or any other electrical appearance, was perceived. The wind was east by south, and so weak that the kite was kept up with great difficulty.

October the 10th, 1775. The weather being clear, and the wind blowing strong from the south west, the kite was raised at eleven o'clock A. M. with ninety yards of string, which had a copper thread twisted in *. The wind, during the experiment, increased and decreased several times; and the Electricity, which was positive, as it appeared by the index of the electrometer, also increased and decreased. At noon the violence of the wind caused the kite to fall. At half past four o'clock, the wind being a little more moderate, the kite was raised again. The Electricity was also positive, and seemed rather stronger than it had been in the morning. The weather at this time was cloudy; the clouds appearing much thicker near the horizon than about the zenith. The kite was pulled down at half

* Such string as this was used in all the following experiments.

paſt five o'clock, and at half after ſeven was raiſed again; every phenomenon continuing the ſame. At eight o'clock, while I was pulling the kite in, I inſulated the ſtring when only thirty-five yards of it were out, and was ſurpriſed to find, that now the Electricity was as ſtrong, as it had been when all the ſtring was out, which was ninety yards long. It muſt however be remarked, that at this time a few flaſhes of lightning were ſeen among the clouds, which were pretty thick about the horizon. At a quarter paſt eleven o'clock the kite was raiſed again, which was the fourth time of raiſing it that day; the weather then being very clear, and the wind the ſame as in the afternoon. The Electricity was very weak, but conſtantly poſitive. The kite was pulled down, after having been up a few minutes only.

October the 16th. At about two P. M. a thick fog being juſt cleared up, the weather became clear, and the wind began to blow from the ſouth-ſouth-weſt. The kite was raiſed with one hundred and twenty yards of ſtring, and it was kept up no

longer than a qurter of an hour. The Electricity was positive, and pretty strong; the index of the electrometer being about 15°. At half past three o'clock the kite was raised again, the weather being very little cloudy. At half past four o'clock the clouds became very thick, and in a short time it began to rain, which increased the Electricity of the kite, without changing its quality; the index of the electrometer arriving to 20°. The kite was pulled down at five o'clock.

October the 18th. After having rained a great deal in the morning, and night before, the weather became a little clear in the afternoon, the clouds appearing separated, and pretty well defined. The wind was west, and rather strong, and the atmosphere in a temperate degree of heat. In these circumstances, at three P. M. I raised my electrical kite with three hundred and sixty feet of string. After that the end of the string had been insulated, and a leather-ball, covered with tin-foil, had been hung to it, I tried the power and quality of the Electricity, which ap-

peared to be poſitive, and pretty ſtrong. In a ſhort time a ſmall cloud paſſing over, the Electricity increaſed a little; but the cloud being gone, it decreaſed again to its former degree. The ſtring of the kite was now faſtened by the ſilk lace to a poſt in the yard of the houſe wherein I lived, which was ſituated near Iſlington, and I was repeatedly charging two coated phials, and giving ſhocks with them:—while I was ſo doing, the Electricity, which was ſtill poſitive, began to decreaſe, and in two or three minutes time it become ſo weak, that it could be hardly perceived with a very ſenſible cork-ball electrometer. Obſerving at the ſame time that a large and black cloud was approaching the zenith (which, no doubt, cauſed the decreaſe of the Electricity) indicating imminent rain, I introduced the end of the ſtring through a window, in a firſt-floor room, wherein I faſtened it by the ſilk lace to an old chair. The quadrant electrometer was ſet upon the ſame window, and was, by means of a wire, connected with the ſtring of the kite. Being now three quarters of an hour after three o'clock, the Electricity was abſo-

lutely

lutely unperceivable; however, in about three minutes time, it became again perceiveable, but now upon trial was found to be negative; it is therefore plain, that its ſtopping was nothing more than a change from poſitive to negative, which was evidently occaſioned by the approach of the cloud, part of which by this time had reached the zenith of the kite, and the rain alſo had begun to fall in large drops.—The cloud came farther on;—the rain increaſed, and the Electricity keeping pace with it, the electrometer ſoon arrived to 15°. Seeing now, that the Electricity was pretty ſtrong, I began again to charge the two coated phials, and to give ſhocks with them; but the phials had not been charged above three or four times, before I perceived that the index of the electrometer was arrived at 35°, and was keeping ſtill increaſing. The ſhocks now being very ſmart, I deſiſted from charging the phials any longer; and, conſidering the rapid advance of the Electricity, thought to take off the inſulation of the ſtring, in caſe that if it ſhould increaſe farther, it might be ſilently conducted to the earth, without cauſing

any bad accident, by being accumulated in the insulated string. To effect this, as I had no proper apparatus near me, I thought to remove the silk lace, and fasten the string itself to the chair; accordingly I disengaged the wire that connected the electrometer with the string; laid hold of the string; untied it from the silk lace, and fastened it to the chair; but while I effected this, which took up less than half a minute of time, I received about a dozen, or fifteen, very strong shocks, which I felt all along my arms, in my breast, and legs; shaking me in such a manner, that I had hardly power enough to effect my purpose, and to warn the people in the room to keep their distance. As soon as I took my hands off the string, the Electricity (in consequence of the chair being a bad Conductor) began to snap between the string and the shutter of the window, which was the nearest body to it. The snappings, which were audible at a good distance out of the room, seemed first isochronus with the shocks which I had received, but in about a minute's time, oftner; so that the people of the house compared their sound to the rattling noise of a

jack

jack going when the fly is off. The cloud now was juſt over the kite; it was black, and well defined, of almoſt a circular form, its diameter appearing to be about 40°; the rain was copious, but not remarkably heavy. As the cloud was going off, the electrical ſnapping began to weaken, and in a ſhort time became unaudible. I went then near the ſtring, and finding the Electricity weak, but ſtill negative, I inſulated it again, thinking to keep the kite up ſome time longer; but obſerving that another larger and denſer cloud was approaching apace towards the zenith, as I had then no proper apparatus at hand, to prevent every poſſible bad accident, I reſolved to pull the kite in; accordingly a gentleman, who was by me, began pulling it in, while I was winding up the ſtring. The cloud was now very nearly over the kite, and the gentleman, who was pulling in the ſtring, told me, that he had received one or two ſlight ſhocks in his arms, and that if he were to feel one more, he would certainly let the ſtring go; upon which I laid hold of the ſtring, and pulled the kite in as faſt as I

could, without any farther obſervation; being then ten minutes after four o'clock.

N. B. There was neither thunder or lightning perceived that day, not indeed for ſome days before or afterwards.

November the 8th, 1775. The wind being north-weſt, and juſt ſufficient, the kite was raiſed at three quarters paſt eleven A. M. with one hundred and twenty yards of ſtring. The Electricity was poſitive, and weak, the weather being cloudy. At noon the clouds grew thicker, and the Electricity quite vaniſhed; however, in a few ſeconds it returned, and from this time it evidently kept increaſing and decreaſing, according as the clouds became thinner or thicker. At forty minutes after one o'clock the Electricity vaniſhed again; a thick cloud then covering almoſt the whole hemiſphere; but as a little rain began to fall, the Electricity returned, and it was ſtill poſitive. At three quarters paſt three o'clock the clouds began to grow thin, and the Electricity increaſed a little; but at this time I was obliged to pull the

kite in. The index of the electrometer in this experiment ſeldom arrived to 6°.

November the 16th. The weather being very clear and froſty, the kite was raiſed at a quarter paſt ten A. M. with one hundred and twenty yards of ſtring. The Electricity was poſitive, and pretty ſtrong, the index of the electrometer going from 9° to 15°; riſing as the wind blew ſtronger, and the kite was more elevated, and *vice verſa*. At a quarter paſt three o'clock the wind, which was north-north-weſt, intirely failing, the kite fell.

November the 17th. The weather being exceedingly damp, and the fog ſo denſe, that the houſes at about a quarter of a mile diſtance could not be diſtinguiſhed, the kite was raiſed at two P. M. with one hundred and ten yards of ſtring, while it was raining, but very little. The Electricity was poſitive, and ſo weak that the cork-balls of an electrometer diverged about three quarters of an inch. The wind being very violent, I was obliged to pull the kite in, after having been up for about five minutes.

December

December the 5th, 1775. The weather being equally cloudy, and the wind weſt by north, and hardly ſufficient, the kite was raiſed at a quarter paſt three P. M. with one hundred and twenty yards of ſtring. The Electricity was poſitive, and ſo weak as to cauſe the cork-ball of an electrometer to diverge about an inch. At a little after four o'clock the kite was pulled in; and at eight o'clock in the evening it was raiſed again. At this time the Electricity was much ſtronger than in the afternoon, but conſtantly poſitive. The weather clearing up, the clouds were driven away by the wind, which was now a little ſtronger than in the afternoon. At forty minutes after eight o'clock the ſky was clear, the moon and ſtars appearing very bright; except that a few thin clouds were yet to be ſeen near the horizon. The index of the electrometer was now going from 15 to 20°. At ten minutes after nine o'clock the kite was drawn in.

N. B. No aurora borealis was to be ſeen.

December

December the 20th. The weather being cloudy and hazy, the kite was raiſed at three quarters after ten o'clock A. M. with one hundred aud forty yards of ſtring. The Electricity was poſitive, and pretty ſtrong, the index of the electrometer going from 16° to 21°. At half paſt one P. M. the weather growing a little clearer, I pulled the kite down; and, after having interpoſed a ſilk ribband between its loop and the extremity of the ſtring, ſo as to inſulate the kite, I raiſed it again with the ſame length of ſtring; and, after I had inſulated the lower extremity of the ſtring, I obſerved that the intenſity of the Electricity, as it appeared by the index of the electrometer, was, as nearly as could be determined, the ſame as before, *i. e.* when the kite was not inſulated with reſpect to the ſtring.

At two o'clock P. M. I pulled the kite down, and found, upon obſervation, that the ſilk ribband had contracted no moiſture, ſo that the kite was perfectly inſulated by it. This experiment of inſulating the kite I have often repeated at other times, and

have

have always met with the same success; hence it appears, that it is the string, and not the kite, which in general collects the Electricity from the air. The kite therefore in general is only useful to extend the string high into the open air.

January the 4th, 1776. The frost having been very hard during the day and night before, the wind began to blow very strong from the south at two o'clock A. M. which occasioned a sudden thaw and a copious rain. At eight o'clock A. M. at which time the kite was raised, the hemisphere appeared like a uniform dark canopy, under which several small, irregular, and darker clouds were running very fast; the rain was constant, but not remarkably heavy. As soon as the string of the kite was insulated, the Electricity, which was negative, began to snap from it, to the shutter of the window and other bodies near; the index of the electrometer arrived to 40°, and it would have certainly gone farther, if the apparatus had been drier; but the air was so damp, that it was almost impossible to keep any part of the apparatus

tus ſufficiently free from moiſture. The Electricity, however gradually decreaſed, ſo that at ten o'clock A. M, at which time the kite was pulled in, the index of the electrometer was at a little above 12°. The coated phials in this experiment were charged ſurpriſingly quick; three or four ſeconds of time being ſufficient to charge two half-pint phials completely.

January the 11th. The ground was covered with ice and ſnow, and the atmoſphere was ſo hazy, that the houſes at a mile diſtance could not be perceived. The wind was ſouth-eaſt by ſouth, and juſt ſufficient to raiſe the kite, which was raiſed at three o'clock P. M. with one hundred and twenty-four yards of ſtring, and kept up till half an hour after midnight. When the kite was firſt raiſed it began to thaw, but as ſoon as it was dark it began to freeze again very hard. The Electricity was poſitive, and pretty ſtrong, the index of the electrometer being about 13°. At half paſt four o'clock I let out thirty-four yards more of ſtring, ſo that all the ſtring the kite now had, was one hundred and fifty-eight

yards.

yards. With this addition of ſtring the Electricity increaſed, ſo that the index of the electrometer arrived to 17°. At half after five o'clock the wind began to increaſe, and the Electricity to decreaſe, until the index of the electrometer arrived to 6°. At three quarters paſt ſix o'clock the index of the electrometer was about 13°, and at ſeven o'clock it arrived at 20°; the wind being now quite eaſt. At a quarter paſt ſeven o'clock the index of the electrometer was about 25°. From this time the wind and the Electricity began both to decreaſe, ſo that at nine o'clock the index of the electrometer was about 10°. At eleven o'clock the wind increaſed. At twelve o'clock the wind was very ſtrong, and the index of the electrometer was about 6°. At half paſt twelve o'clock the index of the electrometer was between 3° and 4°; but the wind being grown very violent, the ſtring broke very near the window, and was loſt with the kite.

N. B. A few minutes after the kite was loſt, it began to ſnow copiouſly.

January the 26th. The froſt being very intenſe, as it had been for about three weeks, and actually ſnowing, I raiſed the kite, with ſeventy yards of ſtring; but before the ſtring was inſulated, it ceaſed to ſnow, and the weather began to clear up, and ſoon became very ſerene. The Electricity was poſitive, and very ſtrong, the index of the electrometer being at about 32°. At eleven o'clock the ſtring broke, and the kite fell, after having been up for above three quarters of an hour.

February the 17th, 1776. The weather being cloudy, rainy, and ſo hazy that the houſes at half a mile diſtance could not be diſcerned, the kite was raiſed at three quarters paſt eleven o'clock A. M. with one hundred and ſeventy-five yards of ſtring. The wind was pretty ſtrong; the Electricity was negative, and alſo ſtrong; the index of the electrometer being about 20°. In about five minutes time the rain ceaſed, the wind weakened, and ſhifted a little towards the ſouth; and the Electricity changed from negative to poſitive. The index of the electrometer was now

about

about 15°. In two or three minutes time, it began to rain again, and continued so for the greatest part of that day; the wind became very weak, and the Electricity changed again from positive to negative, and continued so till half an hour after noon; at which time the wind became so weak that I was obliged to pull the kite in.

February the 19th. The sky being full of pretty well defined clouds, and the wind west-north-west, the kite was raised at half past three o'clock P. M. with one hundred and seventy-five yards of string. The index of the electrometer going from 10° to 20°. At three quarters past three o'clock a dense cloud passed over the kite, which occasioned the index of the electrometer to descend to 4°. As the cloud went away, the electrometer elevated its index. At four o'clock the kite was pulled down.

April the 8th, 1776. The weather was clear, and the northern light very strong.

The

The kite was raiſed for a few minutes at nine o'clock P. M. with one hundred and ſeventy-five yards of ſtring, the wind being north-north-weſt, and pretty ſtrong. The Electricity was poſitive, and, as I could judge, the index of the electrometer would have arrived to 15°.

May the 15th, 1776. The weather being cloudy, and the wind north, the kite was raiſed at three o'clock P. M. with one hundred and ſeventy yards of ſtring. The Electricity was at firſt exceedingly weak, and, as I imagine (for I had not time to examine it) poſitive. But a denſe cloud paſſing over the kite, the Electricity vaniſhed; and, as a few drops of rain fell, a very weak negative Electricity appeared, which ſoon increaſed, ſo as to cauſe the index of the electrometer to arrive to 15°. The rain, however, in a few minutes ceaſed, and the Electricity gradually decreaſed and vaniſhed. A very weak poſitive Electricity immediately took place; but, as another denſer cloud paſſed over, and a few very ſmall drops of rain fell, the poſitive Electricity vaniſhed, and the negative

gative took place. The cloud and rain ſoon went off, and the Electricity became again poſitive, and continued ſo till the kite was pulled down. According as the clouds, which paſſed continually over the kite, were thinner or thicker, ſo the Electricity was more or leſs intenſe; ſometimes cauſing the index of the electrometer to arrive to 5°, and at other times being ſcarce perceivable with the cork-ball electrometer. At five o'clock the kite was pulled in, the weather being then pretty clear, and the index of the electrometer at 3°. The wind, during this experiment, was ſtronger, or weaker, according as the clouds which paſſed over were thicker or thinner. At half paſt ſeven o'clock in the evening of the ſame day, the kite was raiſed again, with the ſame length of ſtring, the wind being then rather ſtrong, and the weather pretty clear. The Electricity was poſitive, and the index of the electrometer ſtood at 10°; but as ſome clouds came from the north, the Electricity began to decreaſe, and by eight o'clock it juſt ſeparated the balls of an electrometer, the hemiſphere being then entirely covered by clouds. At half

 paſt

paſt eight o'clock the kite was pulled down, the clouds over the kite being then very thin, and the index of the electrometer at 5°.

June the 4th, 1776. The weather being cloudy, and the wind on the ſouth-ſouth-weſt, the kite was raiſed at one o'clock P. M. with one hundred and ſeventy yards of ſtring. The Electricity was poſitive, and the index went from 1° to 7°. At three quarters paſt one o'clock the clouds began to be diſſipated, and the Electricity increaſed a little. At two o'clock the kite was pulled in.

June the 17th. The weather being cloudy, and the wind ſouth-weſt, the kite was raiſed at five o'clock P. M. with one hundred and ſeventy yards of ſtring. The Electricity was poſitive, and the index of the electrometer went from 10° to 16°. In this experiment the clouds, whether thicker or thinner, ſeemed to have no effect upon the Electricity of the kite. At a quarter paſt ſix o'clock the kite was pulled in.

June the 20th. The weather being cloudy, and the wind east, and just sufficient, the kite was raised at three quarters past three P. M. with one huudred and seventy yards of string. The Electricity was positive, and the index of the electrometer stood at about 8°. At five o'clock the weather began to clear up, and the Electricity to increase; so that in half an hour's time, the index of the electrometer arrived to 17°; and at six o'clock it stood at 25°. But the wind suddenly failing about this time, the kite fell.

January the 8th, 1777. The weather being frosty and clear, and the wind north, and pretty strong, the kite was raised at four o'clock P. M. with one hundred and seventy yards of string. The Electricity was positive and strong, the index of the electrometer being at 36°. The spark taken from the small prime Conductor was remarkably pungent in this experiment, although it was hardly a quarter of an inch long. At a quarter past five o'clock the kite was pulled in.

General Laws, deduced from the Experiments performed with the electrical Kites.

I. The air appears to be electrified at all times; its Electricity is constantly positive, and much stronger in frosty, than in warm weather *; but it is by no means less in the night than in the day-time †.

II. The presence of the clouds generally lessens the Electricity of the kite: sometimes it has no effect upon it; and it is very seldom that it increases it a little.

* My observations upon the Electricity of the atmosphere have been made in almost every degree of temperature, from 15° to 80° of FARENHEIT's thermometer.

† In all my experiments, it happened only once that the string of the kite gave no signs of Electricity; it was one afternoon, when the weather was warm, and the wind so weak, that the kite was raised with difficulty, and could hardly be kept up for a few minutes; in the evening, however, the wind, which in the day-time had been north-west, shifted to the north-east, blowing a little stronger: I then raised the kite again, being half past ten o'clock, and obtained, as usual, a pretty strong positive Electricity.

III. When it rains, the Electricity of the kite is generally negative, and very ſeldom poſitive.

IV. The aurora borealis ſeems not to affect the Electricity of the kite.

V. The electrical ſpark taken from the ſtring of the kite, or from any inſulated Conductor connected with it, eſpecially when it does not rain, is very ſeldom longer than a quarter of an inch; but it is exceedingly pungent. When the index of the electrometer is not higher than 20°, the perſon that takes the ſpark will feel the effect of it in his legs; it appearing more like the diſcharge of an electric jar, than the ſpark taken from the prime Conductor of an electrical machine.

VI. The Electricity of the kite is in general ſtronger or weaker, according as the ſtring is longer or ſhorter; but it does not keep any exact proportion to it: the Electricity, for inſtance, brought down by a ſtring of a hundred yards, may raiſe the index of the electrometer to 20°; when, with

with double that length of ſtring, the index of the electrometer will not go higher than 25°.

VII. When the weather is damp, and the Electricity is pretty ſtrong, the index of the electrometer, after taking a ſpark from the ſtring, or preſenting the knob of a coated phial to it, riſes ſurpriſingly quick to its uſual place; but in dry and warm weather, it riſes exceedingly ſlow.

Theſe few laws are, in ſhort, the deduction of all my experiments performed with the kites, during the courſe of about two years. How far they may be of uſe, or may coincide with the obſervations of other experimentators, I will not pretend to ſay. My experiments have been performed at Iſlington, and perhaps the reſult of ſimilar ones may be different at other places, eſpecially under different climates; I wiſh, therefore, that they may be accurately repeated in other places, and their reſult may be compared together; in order to determine, if poſſible, ſomething ſatisfactory, relative to the cauſe of that perpetual

Electricity which exiſts in the atmoſphere, and which, very probably, occaſions the Electricity of the clouds, meteors, &c.

CHAP. III.

Experiments performed with the Atmoſpherical Electrometer, and the Electrometer for the Rain.

FIG. 1. of Plate III. repreſents a very ſimple inſtrument, which I have contrived for the purpoſe of making obſervations on the Electricity of the atmoſphere; and which, on ſeveral accounts, ſeems to be the moſt uſeful for that purpoſe. A B is a common jointed fiſhing-rod, without the laſt or ſmalleſt joint. From the extremity of this rod proceeds a ſlender glaſs tube C, covered with ſealing-wax, and having a cork D, at its end, from which a pith-ball electrometer is ſuſpended. H G I is a piece of twine faſtened to the other extremity of the rod, and ſupported at G by a ſmall ſtring F G.

At

At the end I of the twine a pin is faſtened, which, when puſhed into the cork D, renders the electrometer E uninſulated.

When I would obſerve the Electricity of the atmoſphere with this inſtrument, I thruſt the pin I into the cork D, and holding the rod by its lower end A, project it out from a window of the upper part of the houſe into the air, raiſing the end of the rod with the electrometer, ſo as to make an angle of about 50° or 60° with the horizon. In this ſituation I keep the inſtrument for a few ſeconds, and then pulling the twine at H, I diſengage the pin from the cork D; which operation cauſes the ſtring to drop in the dotted ſituation K L, and leaves the electrometer inſulated and electrified, with an Electricity contrary to that of the atmoſphere.—This done, I draw the inſtrument into the room, and examine the quality of the Electricity, without obſtruction either from wind or darkneſs.

With this inſtrument I have made obſervations on the Electricity of the atmo-

ſphere,

ſphere, ſeveral times in a day for ſeveral months, and from them I have deduced the following general obſervations, which ſeem to coincide with thoſe made with the electrical kites.

I. That there is in the atmoſphere, at all times, a quantity of Electricity; for, whenever I uſe the above-deſcribed inſtrument, it always acquires ſome Electricity.

II. That the Electricity of the atmoſphere, or fogs, is always of the ſame kind, namely poſitive; for the electrometer is always negative, except when it is evidently influenced by heavy clouds near the zenith; as appears by the obſervations made on the 19th of October, in the following ſpecimen of the journal.

III. That in general, the ſtrongeſt Electricity is obſervable, in thick fogs, and alſo in froſty weather; and the weakeſt, when it is cloudy, warm, and very near raining; but it does not ſeem to be leſs by night than in the day time.

IV. That

IV. That in a more elevated place the Electricity is ſtronger than in a lower one; for, having tried the atmoſpherical electrometer, both in the ſtone and iron gallery on the cupola of St. Paul's Cathedral, I found that the balls diverged much more in the latter than in the former leſs elevated place; hence it appears, that, if this rule takes place at any diſtance from the earth, the Electricity in the upper regions of the atmoſphere muſt be exceedingly ſtrong.

The following is the moſt remarkable part of the Journal of the obſervations made with the above-deſcribed atmoſpherical electrometer, in which I have noted the Electricity of the electrometer, *i. e.* the contrary of that in the atmoſphere.

N. B. The ſtroke ——— ſignifies *as above.*

Time of obſervation.	Clouds.	Fog.	Wind.	Opening of the electrometer in inches	Quality of the Electricity.
October the 19th, 1776, ½ paſt 10 o'clock	Cloudy	Very little at a diſtance	Very ſtrong	$\frac{1}{10}$	Negative
11	———	———	———	———	———
2	Heavy clouds	———	Violent	$\frac{3}{4}$	Poſitive
¼ paſt 2	Leſs clouds	———	Little	1	———
3	Few at a diſtance	———	———	$\frac{1}{2}$	Negative
November the 6th, 11 o'clock, P. M.		Exceedingly thick	o	1	———
November the 8th, 12 at noon.	o	Hardly any	———	$\frac{1}{4}$	———
11	———	Very little	———	———	———
November the 13th, 10 o'clock, A. M.	Cloudy	Little at a diſtance	Pretty ſtrong	Very little	———
10 P. M.	———	o	———	$\frac{1}{3}$	———
November the 17th, 11 o'clock P. M.	o	———	Violent	$\frac{1}{4}$	———
12	———	———	Very little	———	———
November the 28th, 10 o'clock, A. M.	———	———	Little	$\frac{3}{4}$	———
2	———	———	Hardly any	———	———
December the 20th, ½ paſt 9 o'clock, P. M.	Cloudy	Little	Very little	$\frac{1}{2}$	———
February the 6th, 1777, 2 o'clock, P. M.	———	o	———	$\frac{1}{4}$	———
February the 7th, 12 at noon	———	Little	———	$\frac{3}{4}$	———
8	o	Very little.	Hardly any	$\frac{1}{4}$	———
February the 27th, 12 o'clock, P. M.	Few on the North	o	o	Very little	———
March the 26th, 11 o'clock, P. M.	o	———	———	$\frac{1}{10}$	———

The electrometer for the rain, in principle is nothing more than an insulated instrument to catch the rain, and by a pith-ball electrometer to show the quantity and quality of its Electricity.

Fig. 2. of Plate III. represents an instrument of this kind, which I have frequently used, and after several observations, have found to answer very well. A B C I is a strong glass tube about two feet and a half long, having a tin funnel, D E, cemented to its extremity, which funnel defends part of the tube from the rain. The outside surface of the tube from A to B is covered with sealing-wax; so also is the part of it which is covered by the funnel. F D is a piece of cane, round which several brass wires are twisted in different directions, so as to catch the rain easily, and at the same time to make no resistance to the wind. This piece of cane is fixed into the tube, and a slender wire proceeding from it goes through the bore of the tube, and communicates with the strong wire A G, which is thrust into a piece of cork fastened to the end A of the tube. The end G of the wire AG is formed into a ring, from which

I suspend

I suspend a more or less sensible pith-ball electrometer, as occasion requires.

This instrument is fastened to the side of the window-frame, where it is supported by strong brass hooks at C B, which part of the tube is covered with a silk lace, in order to adapt it better to the hooks. The part F C is out of the window, with the end F a little elevated above the horizon. The remaining part of the instrument comes through a hole in one of the lights of the sash, within the room, and no more of it touches the side of the window than the part C B.

When it rains, especially in passing showers, this instrument, standing in the situation above described, is frequently electrified; and, by the diverging of the electrometer, the quantity and quality of the Electricity of the rain may be observed, without any danger of a mistake. With this instrument I have observed, that the rain is generally, though not always electrified negatively, and sometimes so strongly, that I have been able to charge a small coated phial at the wire A G.

This

This inſtrument ſhould be fixed in ſuch a manner, that it may be eaſily taken off from the window, and replaced again, as occaſion requires; for it will be neceſſary to clean it very often, particularly when a ſhower of rain is approaching.

I ſhall conclude this chapter with the deſcription of a pocket electrometer, fig. 5 and 6. of Plate III. that I have lately conſtructed, and which, on ſeveral accounts, ſeems preferable to thoſe of the moſt ſenſible ſort now in uſe. The caſe, or handle of this electrometer is formed by a glaſs tube, about three inches long, and three-tenths of an inch in diameter, half of which is covered with ſealing-wax. From one extremity of this tube, *i. e.* that without ſealing-wax, a ſmall loop of ſilk proceeds, which ſerves occaſionally to hang the electrometer on a pin, &c. To the other extremity of this tube a cork is adapted, which, being cut tapering on both ends, can fit the mouth of the tube with either end. From one extremity of this cork, two linen threads proceed, a little ſhorter than the length of the tube, ſuſpending each a little *cone* of pith of elder. When

this

this electrometer is to be used, that end of the cork which is opposite to the threads is pushed into the mouth of the tube; then the tube forms the insulated handle of the pith electrometer, as represented fig. 6. Plate III. But when the electrometer is to be carried in the pocket, then the threads are put into the tube, and the cork stops it, as represented fig. 5. The peculiar advantages of this electrometer are, its convenient small size, its great sensibility, and its continuing longer in good order than any other I have yet seen.

Fig. 4. of Plate III. represents a case to carry the above-described electrometer in. This case is like a common tooth-pick case, except that it has a piece of amber fixed on one extremity A, which may occasionally serve to electrify the electrometer negatively, and on the other extremity it has a piece of ivory fastened upon a piece of amber BC. This amber BC serves only to insulate the ivory, which, when insulated, and rubbed against woollen cloths, acquires a positive Electricity; and it is therefore useful to electrify the electrometer positively.

CHAP.

CHAP. IV.

Experiments made with the Electrophorus, commonly called a Machine for exhibiting perpetual Electricity.

IN fig. 9. of Plate III. there are repreſented ſome Plates, commonly called the Machine for exhibiting perpetual Electricity, or the *Electrophorus*. This machine conſiſts of two plates, one of which, B, is a circular glaſs plate, covered on one ſide with ſome ſulphureous or reſinous electric, moſt commonly with a compoſition made of equal parts of roſin, ſhell-lac and ſulphur; the other plate A, is a braſs plate, or a board covered with tin-foil, which is nearly of the ſame dimenſions as the electric plate, and it is furniſhed with a glaſs handle I, which, by means of a braſs or wooden ſocket, is ſcrewed into its center. This machine is the invention of an Italian philoſopher (Mr. VOLTA of Como) and its uſe is the following:

First, the plate B is excited, by rubbing its coated side with a piece of new white flannel, and when excited as much as possible, is set upon the table with the coated side uppermost. Secondly, the metal plate is laid upon the excited electric, as represented in the figure. Thirdly, the metal plate is touched with the finger or any other Conductor, which, on touching the plate, receives a spark from it. Lastly, the metal plate A, being held by the extremity of its glass handle I, is separated from the electric plate; and, after it is elevated above that plate, it will be found strongly electrified, with an Electricity contrary to that of the electric plate, in which case it will give a very strong spark to any Conductor brought near it. By setting the metal upon the electric plate, touching it with the finger, and separating it successively, a great number of sparks may be obtained apparently of the same strength, and that without exciting again the electric plate. If these sparks be repeatedly given to the knob of a coated phial, this will presently become charged.

The action of these plates depends upon a principle long ago discovered, *viz.* the power that an excited electric has to induce a contrary Electricity in a body brought within its sphere of action; the metal plate, therefore, when set upon the excited electric, acquires a contrary Electricity, by giving its electric fluid to the hand, or other Conductor that touches it, when set upon a plate positively electrified; or acquiring an additional quantity of fluid from the hand, &c. when set upon a plate electrified negatively.

As to the continuance of the virtue of this electric plate, when once excited, without repeating the excitation, I think there is not the least foundation for believing it perpetual, as some persons have supposed; it being nothing more than an excited electric, it must gradually lose its power, by imparting continually some of its Electricity to the air, or other substances contiguous to it. Indeed its Electricity, although it could never be proved to be perpetual by experiments, lasts a very long time, it having been observed to be pretty strong

ſeveral days, and even weeks, after excitation. The great duration of the Electricity of this plate, I think, depends upon two cauſes: firſt, becauſe it does not loſe any Electricity by the operation of putting the metal plate upon it, &c.; and, ſecondly, becauſe of its flat figure, which expoſes it to a leſs quantity of air, in compariſon with a ſtick of ſealing-wax, or the like, which being cylindrical, expoſes its ſurface to a greater quantity of air, which is continually robbing the excited electrics of their virtue.

The firſt experiments that I made relative to this machine, were with a view to diſcover which ſubſtance would anſwer beſt for coating the glaſs plate, in order to produce the greateſt effect. I tried ſeveral ſubſtances either ſimple or mixed, and at laſt I obſerved, that the ſtrongeſt in power, as well as the eaſieſt I could conſtruct, were thoſe made with the ſecond ſort of ſealing-wax *, ſpread upon a thick plate of glaſs.

* It is remarkable, that ſometimes they will not act well at firſt; but they may be rendered very good, by ſcraping with the edge of a knife the ſhining or gloſſy ſubſtance

glaſs †. A plate that I made after this manner, and no more than six inches in diameter, when once excited, could charge a coated phial ſeveral times ſucceſſively, ſo ſtrong as to pierce a hole through a card with the diſcharge. Sometimes the metal plate, when ſeparated from it, was ſo ſtrongly electrified, that it darted ſtrong flaſhes to the table upon which the electric plate was laid, and even into the air, beſides cauſing the ſenſation of the ſpider's web upon the face brought near it, like an electric ſtrongly excited. The power of ſome of my plates is ſo ſtrong, that ſometimes the electric plate adheres to the metal, when this is lifted up; nor will they ſeparate, even when the metal plate is

ſubſtance of the wax. This ſeems analogous to the well-known property of glaſs; which is, that new cylinders or globes, made for electrical purpoſes, are often very bad electrics at firſt, but that they improve by being worked, *i. e.* by having their ſurface a little worn. Paper alſo has nearly the ſame property.

† I have lately ſeen ſome of thoſe plates, conſtructed by Mr. G. ADAMS, which acted exceedingly well; and they were made with a compoſition of two parts of ſhell-lac, and one part of Venice turpentine, without any glaſs plate.

touched with a finger, or other Conductor.

If, after having excited the ſealing-wax, I lay the plate with the wax upon the table, and the glaſs uppermoſt, *i. e.* contrary to the common method, then, on making the uſual experiment of putting the metal plate on it, and taking the ſpark, &c. I obſerve it to be attended with the contrary Electricity; that is, if I lay the metal plate upon the electric one, and while in that ſituation touch it with an inſulated body, that body acquires the poſitive Electricity, and the metallic, removed from the electric plate, appears to be negative; whereas it would become poſitive if laid upon the excited wax. This experiment, I find, anſwers in the ſame manner, if an electric plate is uſed which has the ſealing-wax coating on both ſides, or one of Mr. ADAMS's, which has no glaſs plate.

If the braſs plate, after being ſeparated from, be preſented with the edge toward the wax, lightly touching it, and thus be drawn over its ſurface, I find that the Electricity

Electricity of the metal is abſorbed by the ſealing-wax, and thus the electric plate loſes part of its power; and if this operation be repeated five or ſix times, the electric plate loſes its power intirely, ſo that a new excitation is neceſſary in order to revive it.

If, inſtead of laying the electric plate upon the table, it be placed upon an electric ſtand, ſo as to be accurately inſulated, then the metal plate ſet on it acquires ſo little Electricity that it can only be diſcovered with an electrometer; which ſhews that the Electricity of this plate will not be conſpicuous on one ſide of it, if the oppoſite ſide is not at liberty either to part with, or acquire more of the electric fluid. In conſequence of this experiment, and in order to aſcertain how the oppoſite ſides of the electric plate would be affected in different circumſtances, I made the following experiments:

Upon an electric ſtand E, fig. 9. Plate III. I placed a circular tin plate, nearly ſix inches in diameter, which by a ſlender

wire H communicated with an electrometer of pith-balls G, which was also insulated upon the electric stand F. I then placed the excited electric plate D, of six inches and a quarter in diameter, upon the tin plate, with the wax uppermost, and on removing my hand from it, the electrometer G, which communicated with the tin plate, *i. e.* with the under side of the electric plate, immediately opened with negative Electricity. If, by touching the electrometer, I took that Electricity off, the electrometer did not afterwards diverge. But if now, or when the electrometer diverged, I presented my hand open, or any other uninsulated Conductor, at the distance of about one or two inches, over the electric plate, without touching it, then the pith-balls diverged; or if they diverged before, came together and immediately diverged again with positive Electricity;—I removed the hand, and the balls came together;—approached the hand, and they diverged; and so on.

If, while the pith-balls diverged with negative Electricity, I laid the metal plate, holding

holding it by the extremity K of its glaſs handle, upon the wax, the balls came, for a little time, towards one another, but ſoon opened again with the ſame, *i. e.* negative Electricity.

If, whilſt the metallic reſted upon the electric plate, I touched the former, the electrometer immediately diverged with poſitive Electricity, which if, by touching it, I took off, the electrometer continued without divergence.—I touched the metal plate again, and the electrometer opened again; and ſo on for a conſiderable number of times, until the metal plate had acquired its full charge. On taking now the metal plate up, the electrometer G inſtantly diverged with ſtrong negative Electricity.

I repeated the above-deſcribed experiments with this only difference in the diſpoſition of the apparatus, *i. e.* I laid the electric plate D, with the excited ſealing-wax, upon the circular tin plate, and the glaſs uppermoſt; and the difference in their reſult was, that where the Electricity had

been

been positive in the former disposition of the apparatus, it now became negative, and *vice versa*; except that, when I first laid the electric plate upon the tin, the electrometer G diverged with negative Electricity, as well in this as in the other disposition of the apparatus.

I repeated all the above-mentioned experiments with an electric plate, which, besides the sealing-wax coating on one side, had a strong coat of varnish on the other side; and their result was similar to that of those made with the above-described plate.

As to the explanation of these experiments, they seem to depend upon these two well-known principles, *viz.* that a body brought within the sphere of action of an electrified body, does actually acquire the contrary Electricity: and that the existence of one kind of Electricity upon the surface of a substance whatever, causes the existence of the contrary Electricity upon some other substance near it.

CHAP. V.

Experiments on Colours.

HAVING accidentally obſerved that an electric ſhock, ſent over the ſurface of a card, marked a black ſtroke upon a red ſpot of the card, I was from this induced to try what would be the effect of ſending ſhocks over cards painted with different water-colours; accordingly I painted ſeveral cards with almoſt every colour I had, and ſent ſhocks * over them, when they were very dry; making uſe of the univerſal diſcharger, fig. 5. Plate I. The effects were as follow:

Vermilion was marked with a ſtrong black track, about one-tenth of an inch wide. This ſtroke is generally ſingle, as repreſented by AB, fig. 7. of Plate III.; ſometimes it is divided in two towards the

* The force generally employed was the full charge of one foot and a half of coated glaſs.

middle,

middle, like E F; and ſometimes, particularly when the wires are ſet at a conſiderable diſtance of one another, the ſtroke is not continued, but interrupted in the middle, like G H. It often, although not always, happens, that the impreſſion is marked ſtronger at the extremity of that wire from which the electric fluid iſſues, as it appears at E, ſuppoſing that the wire C communicates with the poſitive ſide of the jar; whereas the extremity of the ſtroke, contiguous to the point of the wire D, is neither ſo ſtrongly marked, nor ſurrounds the wire ſo much as the other extremity E.

Carmine received a faint and ſlender impreſſion of a purple colour.

Verdigriſe was ſhook off from the ſurface of the card, except when it had been mixed with ſtrong gum-water, in which caſe it received a very faint impreſſion.

White lead was marked with a ſtrong black track, not ſo broad as that on vermilion.

Red

Red lead was marked with a faint mark, much like carmine.

The other colours I tried, were orpiment, gambodge, ſap-green, red-ink, ultramarine, Pruſſian blue, and a few others, which were compounds of the above; but they received no impreſſion.

It having been inſinuated, that the ſtrong black mark, which vermilion receives from the electric ſhock, might poſſibly be owing to the great quantity of ſulphur contained in that mineral, I was induced to make the following experiment:—I mixed together equal quantities of orpiment and flower of ſulphur, and with this mixture, by the help, as uſual, of very diluted gum-water, I painted a card; but the electric ſhock ſent over it left not the leaſt impreſſion.

Deſirous of carrying this inveſtigation on colours a little further, with a particular view to determine ſomething relative to the properties of lamp-black and oil *, I procured

* It has often been obſerved, that when the lightning has ſtruck the maſts of ſhips, it has paſſed over ſuch

cured ſome pieces of paper painted on both ſides with oil colours, and ſending the charge of two feet of coated glaſs over each of them, by making the interruption of the circuit upon their ſurfaces, I obſerved that the pieces of paper painted with lamp-black, Pruſſian-blue, vermilion, and purple brown, were torn by the exploſion, but white lead, Naples yellow, Engliſh ochre, and verdigriſe remained unhurt.

The ſame ſhock ſent over a piece of paper painted very thickly with lamp-black and oil left not the leaſt impreſſion. I ſent the ſhock alſo over a piece of paper unequally painted with purple brown, and the paper was torn where the paint laid very thin, but remained unhurt where the paint was evidently thicker. Theſe experiments I repeated ſeveral times, and with ſome little variation, which naturally produced

ſuch parts of the maſts which were covered with lamp-black and tar, or painted with lamp-black and oil, without the leaſt injury, at the ſame time that it has ſhivered the uncoated parts, in ſuch a manner as to render the maſts uſeleſs. For a particular account of ſuch facts, ſee the Phil. Tranſ. vol. XLVIII. and LXVII.

different

different effects; however, they all seem to point out the following proposition.

I. A coat of oil paint, over any substance, defends it from the effects of such an electric shock, as would otherwise injure it; but by no means defends it from any electric shock whatever. II. No one colour seems preferable to the others, if they are equal in substance, and equally well mixed with oil; but a thick coating does certainly afford a better defence than a thinner one.

By rubbing the above-mentioned pieces of paper, I find that the paper painted with *lamp-black and oil* is more easily excited, and acquires a stronger Electricity, than the papers painted with the other colours; and perhaps on this account it may be, that lamp-black and oil might resist the shock somewhat better than the other paints.

It is remarkable, that vermilion receives the black impression, when painted with linseed-oil, nearly as well as when painted with water. The paper painted with white lead and oil, receives also a

black mark; but its nature is very ſingular. The track, when firſt made, is almoſt as dark as that marked on white lead, painted with water, but it gradually loſes its blackneſs, and in about one hour's time (or longer, if the paint is not freſh) it appears without any darkneſs; and when the painted paper is laid in a proper light, appears only marked with a colourleſs track, as if made by a finger nail. I ſent the ſhock alſo over a piece of board, which had been painted with white lead and oil about four years before, and the exploſion marked the black track upon this alſo; this track however was not ſo ſtrong, nor vaniſhed ſo ſoon as that marked upon the painted paper, but in about two days time it alſo vaniſhed intirely.

CHAP.

CHAP. VI.

Promiscuous Experiments.

OBserving that a strong spark may be obtained from the metal plate belonging to Mr. VOLTA's machine, described in the fourth chapter of this Part, when not the least spark can be obtained from the electric plate itself, I was naturally induced to make use of the above-mentioned metallic plate, to discover the Electricity of very weak electrics; which otherwise would be either inobservable, or so small as not to permit its quality to be ascertained. Accordingly I constructed several such plates of different sizes, beginning with that of a common metal button fastened with a stick of sealing-wax; and by using them, I obtained a very sensible Electricity from the hairs of my legs, when stroked, and of my head, or any part that I have tried of my body, or the head of almost any other person.

In this manner I obtain ſuch ſtrong ſparks from the back of a cat, a hare's ſkin, a rabbit's ſkin, a piece of flannel, or of paper, that I can preſently charge a coated phial with either of thoſe, and ſo ſtrongly, as to pierce a hole through a card with its diſcharge.

I have often obſerved that, when ſtroking a cat with one hand, and holding it with the other, I feel frequent ſmart prickings on different parts of that hand which holds the animal. In theſe circumſtances, very pungent ſparks may be drawn from the tips of the ears of the cat.

Smooth glaſs rubbed with a rabbit's ſkin, dry and warm, acquires, I find, the *negative* Electricity; but if the ſkin is cold, the glaſs is excited poſitively. Sometimes ſmooth glaſs may be excited negatively with new white flannel, clean and dry, and alſo with hare's ſkin.

Obſerving the ſtrong electric power of new white flannel, I thought that a piece of it, rolled round the globe of an electrical

machine, would perhaps give a ſtronger Electricity to the prime Conductor than the glaſs itſelf. In order to try the truth of my ſuppoſition, I tied a large piece of flannel, dry and warm, round the globe of the machine, and, for a rubber, I applied the palm of my hand; then turned the winch, firſt ſlowly, and afterwards briſkly; but, contrary to my expectation, the Electricity at the prime Conductor, although poſitive, was ſo weak, that the index of the quadrant electrometer was not moved from its pependicular ſituation. Surpriſed at this event, I reſolved to take off the apparatus; but I was more ſurpriſed, when, on removing the flannel from the globe, the former appeared ſo ſtrongly poſitive, that it darted ſeveral ſparks to my arm, and other contiguous bodies, and the latter remained ſo ſtrongly negative, that the electrometer upon the prime Conductor inſtantly elevated its index to about 45°. This experiment being ſeveral times repeated, produced always the ſame effect.

Having had occaſion to coat a ten ounce phial for the Leyden experiment, I ſtuck

the braſs filings on the inſide of it with varniſh, agreeable to the directions given by ſome writers on Electricity. This phial remained about a week unuſed; but it happened, that whilſt I was charging and diſcharging it for ſome experiments, on making a diſcharge, it exploded with a greater noiſe than uſual, the cork with the wire being at the ſame time blown out of the neck of it. Being intent upon the main experiments in hand, I omitted to examine this phenomenon; — I replaced the cork into the neck of the phial, and went on charging and diſcharging it again; but it had not been charged above three or four times more, when, on making a diſcharge, the varniſh that ſtuck the braſs filings was in a flame, which burnt the under ſide of the cork, and occaſioned a good deal of ſmoke and flame to come out of the phial. Some days after, this experiment was repeated in the preſence of three gentlemen, well verſed in Electricity, when the cork with the wire was alſo puſhed out of the neck of the phial; but the varniſh was this laſt time ſo far burnt, that the braſs filings were almoſt all dropped to the

the bottom of the phial, and had their colour changed by the combuſtion.

In making ſome experiments, of a nature rather different from Electricity, I accidentally obſerved, that when I agitated ſome quickſilver in a glaſs tube, hermetically ſealed, and in whoſe cavity the air was very much rarefied, the outſide of the tube appeared ſenſibly electrified; its Electricity however was not conſtant, nor, as I firſt thought, in proportion to the agitation of the quickſilver. Being deſirous of aſcertaining the properties of ſuch tubes, I conſtructed ſeveral of them, and by means of two cork-ball electrometers, obſerved their properties; but as they all agree in regard to the chief points, I ſhall only deſcribe one, which is the beſt of them. This tube is repreſented by fig. 3. of Plate III. Its length is thirty-one inches, and its diameter is little leſs than half an inch. The quickſilver in it may be about three-fourths of an ounce; and in order to exhauſt it of air, I cloſed it while the quickſilver was boiling in its oppoſite end.

Before this tube is uſed, I make it a little warm, and clean it; then holding it nearly horizontal, I let the quickſilver in it run from one end of the tube to the other, by gently and alternately elevating and depreſſing its extremities. This operation immediately renders the outſide of the tube electrical, but with the following remarkable property, *viz.* that end of the tube, where the quickſilver actually ſtands, is poſitive, and all the remaining part is negative. If by elevating this poſitive end of the tube a little, I let the quickſilver run to the oppoſite end, which was negative, then the former inſtantly becomes negative, and the latter poſitive. The poſitive end has always a ſtronger Electricity than the negative, If when one end of the tube, for inſtance A, is poſitive, *i. e.* when the quickſilver is in it, I do not take off that Electricity by touching it; then on elevating this end A, ſo as to let the quickſilver run to the oppoſite end B, it appears negatively electrified in a very ſmall degree. If by depreſſing it again it be rendered poſitive a ſecond time, and that poſitive Electricity be not taken off, then, on elevat-

ing

ing this end A again, it appears to be positive in a ſmall degree; but if whilſt it is poſitive, its Electricity be taken off, then, on being elevated, it appears ſtrongly negative.

When about two inches of each extremity of this tube is coated with tin-foil as it appears in the figure, that coating aſſiſts to render the Electricities at the extremities of the tube more conſpicuous, ſo that ſometimes they give ſparks to a Conductor brought near.

In regard to the conſtruction of ſuch tubes (which I have made of ſeveral lengths, from nine to thirty-one inches) it is obſervable, that ſome will act very well, while others will hardly acquire any Electricity at all, even when they are made very hot. I am not yet thoroughly ſatisfied in reſpect to this difference, but ſuſpect that the thickneſs of the glaſs is more concerned, than any thing elſe; it appearing that a tube, whoſe glaſs is about one-twentieth of an inch thick, anſwers better than either a thicker or a thinner one.

The following Chapters contain the account of some experiments, which I made since the first publication of this Book; for which reason, I deemed proper to relate them apart, without altering the preceding chapters, with the contents of which they are however connected.

CHAP. VII.

An Account of some new Experiments in Electricity, with the Description and Use of two new Electrical Instruments.

PRofessor LICHTENBERG of Gottingen, some time ago made an experiment upon the electrophorus, an account of which was first received in London towards the latter end of the year 1777. The phenomena attending the experiment are very entertaining and various, but I do not know that any person ever offered a satisfactory explanation of them. The author himself, in his paper entitled " *De nova methodo naturam ac motum fluidi electrici investigandi Commentatio prior,*" wherein he gives

gives an account of the experiments, does not attempt any explanation of it; contenting himſelf with the account only of various particulars attending it.—In brief, the experiment is as follows:

The electrophorus, that is, a plate of ſome reſinous ſubſtance, as ſulphur, roſin, gum-lac, &c, is firſt excited, either by rubbing or otherwiſe; then a piece of metal of any ſhape, at pleaſure, as for inſtance, a three-legged compaſs, a piece of braſs tube, or the like, is ſet upon the electrophorus, and to this piece of metal ſo placed, a ſpark is given, of the Electricity contrary to that of the plate; this done, the piece of metal is removed, by means of a ſtick of ſealing-wax or other electric, and ſome powder of roſin, kept in a linen bag, is ſhaken upon the electrophorus: this powder wlll be found to fall about thoſe points upon the plate, which the piece of metal touched, forming ſome radiated appearances, much like the common repreſentations of ſtars; at the ſame time, upon the greateſt part of the plate, that is, beſides thoſe ſtars, there is hardly any powder

at all. Now, it is to be remarked, that if the plate be excited negatively, and the ſpark given to the metal ſet upon it is poſitive, the appearance will be as above-deſcribed; but if, on the contrary, the plate is poſitive and the ſpark is negative, then the powder of roſin will be found to fall upon thoſe parts of the plate which in the other caſe it left uncovered, and to leave the ſtars clean; in ſhort, it will do juſt the reverſe of what it did in the other caſe; or, in other words, the powder of roſin will be attracted by thoſe parts only of the electrophorus which are electrified poſitively.

When I firſt obſerved theſe phenomena, I thought there was no apparent reaſon why the powder of roſin ſhould be attracted by thoſe parts of the electrophorus which are poſitively electrified, and not by thoſe which are negative. The two Electricities are certainly contrary to one another; but either of them attracts a non-electrified body. Inſiſting upon this conſideration, I thought that the experiment could be explained only upon the ſuppoſition, that the powder of roſin, on its falling from the linen

linen bag was actually electrified negatively; in which caſe it would have been eaſy to account for the phenomena, upon the well-known principle of bodies contrarily electrified attracting each other, and repelling one another when poſſeſſed of the ſame kind of Electricity.

In order to try the reality of my ſuppoſition by experiments, I inſulated a braſs plate upon a glaſs ſtand, and connected a very ſenſible electrometer with it; then began ſhaking the powder of roſin upon it, in the ſame manner as I had done upon the electrophorus, and in a few ſeconds time had the pleaſure to ſee the electrometer diverge with a very manifeſt degree of negative Electricity, anſwering my expectations exactly. The explanation of the ingenious Profeſſor LICHTENBERG'S experiment, now became very eaſy and natural; for the powder of roſin being actually electrified negatively, could not be attracted, except by thoſe parts of the electrophorus which are in a contrary ſtate, *i. e.* electrified poſitively. It is obſerved, that powder of roſin anſwers better for this experiment

than

than the powders of other ſubſtances; and accordingly I find that this powder, when ſhaken upon the inſulated braſs plate, ſhews a ſtronger degree of Electricity than the other powders. Indeed, the Electricity of the powder of roſin, not only when ſhaken upon the braſs plate in the manner above-mentioned, but ſimply let fall upon it from a piece of paper, a ſpoon, &c. is very great; half an ounce of this powder being ſuffici-ent, to let the threads of the electrometer diverge as much as they poſſibly can.

This diſcovery not only affords an eaſy explanation of Profeſſor LICHTENBERG's experiment upon the electrophorus, but ſhews a method of exciting powders, which has long been a deſideratum in the ſcience of Electricity. The method is as follows: —Inſulate a metal plate upon an electric ſtand, and connect with it a cork-ball electrometer; then the powder required to be tried, being held in a ſpoon, or other thing, at about ſix inches above the plate, is to be let fall gradually upon it. In this manner the Electricity acquired by the powder, being communicated to the metal plate,

plate, and to the electrometer, is rendered manifest by the divergence of the threads; and its quality may be ascertained in the usual manner. See fig. the 4th of Plate IV.

It must be observed, that if the powder is of a conducting nature, like the amalgam of metals, sand, &c. it must be held in some electric substance, as a glass phial, a plate of sealing-wax, or the like. Sometimes the spoon that holds the powder may be insulated; in which case, after the experiment, the spoon will be found possessed of an Electricity contrary to that of the powder.

In performing these experiments, care must be had to render the powders, and whatever they are held in, as free from moisture as possible; sometimes it being necessary to make them very warm, otherwise the experiment is apt to fail. The following are the particulars which I have observed with this new method, which however are neither numerous, nor often repeated; but they may suffice to excite

the curiosity of those persons, who have leisure and the opportunity of repeating them more at large and in a greater variety.

Powder of rosin, whether it be let fall from paper, glass, or a metal spoon, electrifies the plate strongly negative; the spoon, if insulated, remaining strongly positive. Flower of sulphur produces the same effect, but in a little less degree. Pounded glass, let fall from a piece of paper, made dry and warm, electrifies the plate negatively, but not in so strong a degree as rosin. If it be let fall from a brass cup, it electrifies the plate positively, but in a very small degree.

Steel-filings let fall either from a glass phial or paper, electrify the plate negatively; but brass-filings, treated in the same manner, electrify the plate positively. The amalgam of tin-foil and mercury, gunpowder, or very fine emery, electrify the plate negatively, when they are let fall upon it from a glass phial. Quicksilver, from

a glaſs phial, electrifies the plate poſitively.

Soot from the chimney, or the aſhes of common pit-coals mixed with ſmall cinders, electrify the plate negatively, when let fall from a piece of paper.

Deſcription of the improved atmoſpherical Electrometer.

Fig. the 2d of Plate IV. is a geometrical repreſentation of my new atmoſpherical electrometer, in its real ſize; this inſtrument, whoſe firſt hint I received from my friend T. RONAYNE, Eſq; after various trials, I brought to the preſent ſtate of perfection, as long ago as the year 1777; and immediately after, ſeveral of them were made after my pattern by Mr. ADAMS, philoſophical inſtrument maker, in Fleet Street. The great difficulty attending the conſtruction of this inſtrument, has long diſſuaded my publiſhing any deſcription of it; nor had I ever preſented the deſcription of it to the Royal Society, if the obſervations of ſeveral of my friends, who have uſed it, in England and abroad, joined to my own repeated experiments, had not indiſputably confirmed

confirmed its ſuperiority over any other inſtrument of that kind. Its particular advantages are: I. The ſmallneſs of the ſize *; II. Its being always ready for experiments, without fear of entangling the threads, or having an equivocal reſult by the ſluggiſhneſs of its motion; III. Its being not diſturbed by wind or rain; IV. Its great ſenſibility; and V. Its keeping the communicated Electricity longer than any other Electrometer.

The principal part of this inſtrument is a glaſs tube C D M N, cemented at the bottom into the wooden piece A B, by which part the inſtrument is to be held when uſed for the atmoſphere; and it alſo ſerves to ſcrew the inſtrument into its wooden caſe A B O, fig. I. when it is not to be uſed †. The upper part of the tube C D M N, is ſhaped tapering to a ſmaller extremity, which is entirely covered with ſealing-wax, melted by heat, and not diſ-

* Some time ago I made one ſo ſmall, that its caſe, which is of braſs, meaſures only $3\frac{1}{1}$ inches in length and $\frac{9}{10}$ of an inch in diameter, aud yet it acts exceeding well.

† The whole caſe of this electrometer has been made alſo of braſs, and has been found to anſwer better than wood, as it does not warp.

ſolved

ſolved in ſpirits. Into this tapering part a ſmall tube is cemented, the lower extremity G of which being alſo covered with ſealing-wax, projects a ſhort way within the tube C D M N. Into this ſmaller tube a wire is cemented, which with its lower extremity touches the flat piece of ivory H, faſtened to the tube by means of cork; the upper extremity of the wire projects about a quarter of an inch above the tube, and ſcrews into the braſs cap E F, which cap is open at the bottom, and ſerves to defend the waxed part of the inſtrument from the rain, &c. In fig. 3. a ſection of this braſs cap is repreſented, in order to ſhew its internal ſhape, and the manner in which it is ſcrewed to the wire, projecting above the tube L. The ſmall tube L, and the upper extremity of the large tube C D M N, appear like one continued piece, on account of the ſealing-wax, which covers them both. The conical corks P of this electrometer, which by their repulſion ſhew the Electricity, &c. are as ſmall as can conveniently be made, and they are ſuſpended by exceedingly fine

ſilver wires. Theſe wires are ſhaped in a ring at the top, by which they hang very looſely on the flat piece of ivory H, which has two holes for that purpoſe. By this method of ſuſpenſion, which is applicable to every ſort of electrometer, the friction is leſſened almoſt to nothing, and thence the inſtrument is ſenſible of a very ſmall degree of Electricity. I M, and K N, are two narrow ſlips of tin-foil, ſtuck to the inſide of the glaſs C D M N, and communicating with the wooden bottom A B;—they ſerve to convey off that Electricity, which, when the corks touch the glaſs, is communicated to it, and being accumulated, might diſturb the free motion of the corks.

In regard to its uſe, this inſtrument may ſerve to obſerve the artificial, as well as the atmoſpherical Electricity. When it is to be uſed for artificial Electricity, this electrometer is ſet upon a table or other convenient ſupport; then it is electrified by touching the braſs cap E F with an electrified body, which Electricity will ſome-

times

times be preſerved for more than an hour*; in this ſtate, if any electrified ſubſtance be brought near the cap E F, the corks of the electrometer, by their converging or by increaſing their divergency, will ſhew the ſpecies of that body's Electricity.

Before we proceed, it is neceſſary to remark, that to communicate any Electricity to this electrometer, by means of an excited electric, *e. g.* a piece of ſealing-wax (which we ſuppoſe as always negatively electrified) is not very readily done in the uſual manner, on account of the cap E F being well rounded, and free from points or ſharp edges. By the approach of the wax, the electrometer will be cauſed to diverge; but as ſoon as the wax is removed, the wires immediately collapſe. The beſt method to electrify it, is to bring the excited wax ſo near the cap, that one or both the corks may touch the ſide of the bottle C D M N; after which, they will ſoon collapſe and appear unelectrified; if now the wax be re-

* I once made an electrometer of this ſort, which could remain electrified for above 12 hours, and that in a room without fire.

moved, they will again diverge, and remain electrified poſitively.

In this operation, the wax does not impart any of its Electricity to the electrometer, but only acts by means of its atmoſphere, *viz.* when the excited wax is firſt brought near the braſs cap E F, (agreeable to the well-known law of Electricity, and according to Dr. FRANKLIN's hypotheſis) it determines the electric fluid naturally belonging to the corks, towards the cap; hence the corks repel each other. Now, if in this ſtate they touch the ſides of the glaſs C D M N, they acquire from it a quantity of electric fluid equal to that which, by the action of the excited wax, was driven towards the cap; conſequently they collapſe, and appear unelectrified. Notwithſtanding this appearance, the cap is actually overcharged; ſo that when the wax is removed, the overplus of the electric fluid, which the corks had acquired from the glaſs and tin-foil ſtuck upon it, and which was crowded upon the cap, on account of the negative atmoſphere of the wax, now diffuſes itſelf equally through the cap,

the wires, the corks, &c. and therefore the corks repel each other with poſitive Electricity.

If, inſtead of the ſealing-wax excited negatively, an electric poſſeſſed of poſitive Electricity be uſed, the electrometer acquires the negative Electricity, and the explanation, *mutatis mutandis*, is the ſame as above.

By conſidering this remark it will appear, that when this electrometer is electrified either poſitively or negatively, and an electrified body be brought towards the braſs cap, the Electricity of that body will be of the ſame kind with that of the electrometer, if the corks increaſe their divergency; but it will be of the contrary kind, if the corks approach one another.

When this inſtrument is to be uſed to try the Electricity of the fogs, the air, the clouds, &c. the obſerver is to do nothing more than to unſcrew it from its caſe, and, holding it by the bottom A B, to preſent it to the open air, a little above his head, ſo

that he may conveniently ſee the corks P, which will immediately diverge if there be any ſufficient quantity of Electricity; whoſe nature, *i. e.* whether poſitive or negative, may be aſcertained by bringing an excited piece of ſealing-wax, or other electric, towards the braſs cap E F.

It is perhaps unneceſſary to remark, that this obſervation muſt be made in an open place, as the roads out of town, the fields, the top of a houſe, &c.

In the roads between Iſlington and London, I have often made uſe of this inſtrument: by which I have confirmed the obſervations of THOMAS RONAYNE, Eſq; who firſt diſcovered the Electricity of the fogs, as teſtified by a paper of his publiſhed in the Phil. Tranſactions; and who has remarked, that a fog is very rarely not electrified, but in froſty weather the air is conſtantly electrified.

Promiſcuous Experiments.

Having had frequent occaſion to obſerve how difficult it is to deprive ſealing-wax of

of its Electricity entirely, after it has been well excited, I had the curiosity to try whether water could effect it; in order to that, I tied a stick of sealing-wax to a silk string, about a yard long, and after having excited it very powerfully with flannel, I plunged it in a tin vessel full of water, and immediately drawing it out, brought a very sensible electrometer near it, and observed, that at first it shewed no sign of Electricity, but in about half a minute's time it manifested a small, but very sensible degree of negative Electricity. A glass tube treated in the same manner, was deprived of all its Electricity by the water.

I have often remarked, that after having excited a glass tube with the amalgamed rubber, in the usual manner, the part of it which had been under my hand was negative. This *minus* state was still more conspicuous, when I grasped with my hand the part next above, *viz.* part of that which had been excited positively by rubbing. In the same manner, when I excite a stick of sealing-wax by rubbing it with flannel, I often find, that the part of it

which I have held with my hand is in a contrary ſtate of Electricity, *viz.* poſitive.

Being deſirous of trying the conducting power of the effluvia of burning bodies, in a manner more ſatisfactory than it had hitherto been done, I contrived an inſtrument for that purpoſe, which is repreſented in fig. 5 *. The handle of it, A B, is a glaſs tube, into the extremity B of which, a wire E I, and a ſmaller glaſs tube B C, are cemented by means of ſealing-wax. From the extremity of this ſmall tube, another wire G F proceeds, which, as well as the wire E I, is bent at top, ſo that the extremities of both wires E F may be about one-tenth of an inch from one another. G H is a ſmall wire, faſtened to the wire F G, and to the extremity of the handle, ſo that when the inſtrument is held in one's hand, this wire touches the hand. K is a ſmall cork-ball electrometer, which, when the inſtrument is to be uſed, is affixed to the pin D, which proceeds from the wire I E. When ex-

* This fig. is half the real ſize of the inſtrument.

periments

periments are to be tried with this inſtrument, the electrometer K muſt be affixed to the pin D, and muſt be electrified ſo that the cork-balls may diverge as far as poſſible: this done, the extremities E F of the wires are brought within the effluvia that are to be tried, which, if they are of a good conducting nature, will complete the communication between the two wires E F, and diſcharge the electrometer of its Electricity; otherwiſe the electrometer will remain electrified for a conſiderable time. The experiments which I made with this inſtrument are neither numerous, nor ſo often repeated, as to be depended upon; excepting one only, which perhaps it will not be uſeleſs to mention: I found that the fumes ariſing by the action of a lens from the amalgam of tin-foil and mercury, conducted ſo badly, that the electrometer loſt its Electricity in a time very little leſs than is required without any fumes whatever.

CHAP.

CHAP. VIII.

Experiments concerning the Effects of Electricity in Vacuo.

BEFORE we begin with the narration of the experiments made with a view of aſcertaining the effects of Electricity in vacuo, it will be proper to mention the ſtate of knowledge relating to electric attraction and repulſion, conducting power, and the appearance of electric light in vacuo.

The inquiſitive Mr. BOYLE, towards the latter end of the laſt century, obſerved, that excited electrics would attract in the vacuum of his air pump; in conſequence of which he concluded, that the preſence or abſence of air did not interfere with electric attraction. In the beginning of the preſent century Mr. GREY repeated Mr. BOYLE's experiments, and, like him, found that electrics would attract at nearly the ſame diſtance in vacuo as in air. He likewiſe made ſome other experiments in vacuo, concerning

concerning electric attraction and repulsion, from which the same deductions could be inferred. After Mr. GREY divers other ingenious persons repeated such-like experiments, and came to very nearly the same conclusion; but F. BECCARIA seems to have been the first person who asserted, that in a perfect vacuum there is no electric attraction, and his assertion is certainly true.

As for the electric light in vacuo, numerous observations concerning its diffusibility and various shades of its colours in a moderate degree of exhaustion, have been made with sufficient accuracy by Mr. HAUKSBEE, Mr. du FAY, Abbé NOLLET, F. BECCARIA, and others, who likewise observed that the vacuum was a conductor of electricity; but it is related by Dr. PRIESTLEY, in his first volume of experiments and observations on different sorts of permanently electric fluids, that Mr. WALSH, assisted by Mr. de LUC, having made a double barometer, in which the quicksilver had been accurately boiled so as to expel all the air from the tube, found that the vacuum in the arched part of this double barometer

was

was not a conductor of Electricity, nor any electric light could be seen in it. This remarkable discovery was lately confirmed by some ingenious experiments of Mr. Morgan, described in the 75th vol. of the Phil. Transf.; but my experiments, which are related in this chapter, were made not with a torricellian vacuum, but with an excellent air-pump, a description of which is to be found in the Phil. Transf. vol. 73d *.

Experiment I.

In a glass receiver, of six inches diameter and nine inches in height, having a brass cap, a brass wire of $\frac{1}{5}$ of an inch in diameter was fixed to its cap, and proceeding through the middle of the receiver, its lower extremity was five inches distant from the aperture of the receiver, and of course of the plate of the air-pump, when the receiver was placed upon it. A fine linen thread was fastened towards the top of the wire, and about four inches of it hanged freely along the brass wire, and almost in contact with it.

* An account of those experiments was read at the Royal Society in November 1784.

The extremity of the wire, which paffing through the brafs cap projected out of the receiver, was furnifhed with a ball. Thus prepared, the receiver was placed upon the plate of the pump, without any leather, or any thing elfe befides a little oil on its outfide edge, which muft be always underftood in all the other experiments related in the courfe of this chapter. Then the exhauftion was commenced, and at intervals fome Electricity was communicated, either by the approach of the Conductor of an electrical machine, or the knob of a charged jar, to the brafs ball of the wire, in order to obferve the quantity of the repulfion of the thread from the wire in different degrees of rarefaction, which degrees were afcertained by the fhort barometrical gage. Proceeding in this manner, it was obferved, that till the rarefaction did not exceed one hundred, to wit, till the air remaining within the receiver was not lefs than the hundredth part of the original quantity, whenever the Electricity was communicated to the brafs ball, the thread firft adhered to the wire, and then was repelled by it; though this repulfion became fmaller and fmaller, according as the exhauftion

came nearer to the above-mentioned degree. The clinging of the thread to the wire firft, was becaufe, being dry, it required fome time before it acquired a fufficient quantity of Electricity from the wire, and confequently it was not immediately repelled. When the air within the receiver was exhaufted above one hundred times, the thread was not firft attracted and then repelled as before, but only vibrated a little backwards and forwards, and then remained in the fituation in which it ftood when Electricity was not concerned. By exhaufting the receiver ftill farther, the vibration of the thread when electrified was gradually diminifhed; fo that when the degree of rarefaction was above five hundred, fparks and the difcharge of a jar only made the thread vibrate in a manner juft fenfible; but this vibration, however fmall, did never become quite infenfible, even when the receiver was exhaufted to the utmoft power of the pump, which was very near one thoufand. After this the air was gradually admitted into the receiver, and at various intervals the ball of the brafs wire was electrified, in order to obferve whether the fame phenomena appeared at the different

degrees

degrees of exhauſtion as had done before; and they were found to agree with ſufficient exactneſs.

EXPERIMENT II.

The braſs wire within the ſame glaſs receiver was made very ſhort, and from its extremity, a fine linen thread, ſix inches long, was ſuſpended; and upon the plate of the pump a ſmall braſs ſtand with a braſs pillar was placed; ſo that when the receiver was put upon the plate, and over the braſs ſtand, about one inch length of the thread ſtood parallel to, and at various required diſtances from, the braſs pillar *. In this diſpoſition of the apparatus, whenever any the leaſt quantity of Electricity was communicated to the knob of the braſs wire, the thread was immediately attracted by the braſs pillar, and adhered to it ſome time, becauſe, being dry, it did not immediately part with the acquired Electricity. At various degrees of exhauſtion, the electricity being communicated to the braſs ball of the wire, it was found, that the

* This diſtance was altered by turning the braſs wire which paſſed through a collar of leather in the braſs cap of the receiver.

thread

thread was always attracted by the braſs pillar, though from a greater or leſs diſtance, according as a greater or leſs quantity of air remained within the receiver. Thus when the air was rarefied about one hundred times, the thread was attracted from about one inch; when the air was rarefied two hundred times, it was attracted from about $\frac{1}{8}$ of an inch; when the air was rarefied three hundred times, it was attracted from about $\frac{1}{10}$; and after this it was always attracted from about one-twentieth, even when the air within the receiver was rarefied about one thouſand times. It is remarkable, that when the air in the receiver is rarefied about three hundred times, if a jar be diſcharged through the vacuum, by touching the ball of the wire on the receiver with its knob, the thread is not in conſequence of it attracted by the braſs pillar; the reaſon of which ſeems to be, becauſe that large quantity of Electricity opens at once a way through the vacuum, and paſſes through every part of it; whereas a ſmall quantity of Electricity, even the action of a ſmall electrical machine in the ſame room, at no very great diſtance from the apparatus,

apparatus, will cauſe the thread being attracted by the braſs pillar.

EXPERIMENT III.

The braſs ſtand, with the pillar, and the thread which proceeded from the wire, being removed from under the receiver, a very ſenſible electrometer was faſtened, inſtead of the thread, to the extremity of the braſs wire. This electrometer conſiſted of two very fine ſilver wires, each about one inch long, and having a ſmall cone of cork at its extremity. The ſenſibility of ſuch an electrometer is really ſurpriſing; for even the Electricity of a ſingle hair excited, does ſenſibly affect it; and, as its ſuſpenſion is almoſt without any friction or other impediment, it never deceives one by appearing to be electrified when in reality it is not ſo. With this preparation, the receiver being placed upon the plate of the air-pump, the air was gradually exhauſted, and at intervals ſome Electricity was communicated to the ball on the outſide of the receiver, either by an excited electric or by a charged jar, and it was found that the corks of the electrome-

ter were always made to diverge by it, even when the air was exhaufted as much as poffible. Indeed their divergency was fmaller and fmaller, and lafted a fhorter time, according as the air was more exhaufted, but it was vifible to the laft.

In this experiment, analogous to what has been obferved in the preceding, when the air was exhaufted above three hundred times, if a jar was difcharged through the vacuum, or a ftrong fpark was given to the knob on the top of the receiver, the corks of the electrometer diverged very little indeed, and but for an inftant; whereas a fmall quantity of Electricity made them diverge more, and remain much longer in that ftate.

It feems deducible from thofe experiments, that electric attraction and repulfion take place in every degree of rarefaction, from the loweft to about one thoufand, but that the effect diminifhes, in proportion as the air is more and more rarefied; and by following this low, we may perhaps conclude with F. BECCARIA, that there is no electric attraction nor repulfion in a perfect vacuum:

cuum: though this will perhaps be impoſſible to be verified experimentally, becauſe when in an exhauſted receiver no attraction or repulſion is obſerved between bodies to which Electricity is communicated, it will be only ſuſpected, that thoſe bodies are not ſufficiently ſmall and light. But if we conſult reaſon, and which alone ought to aſſiſt us when deciſive experiments are not practicable, it ſeems likely that electric attraction and repulſion cannot take place in a perfect vacuum, by which I only mean a perfect abſence of air. For either this vacuum is a Conductor or a Non-conductor of Electricity; if a Conductor, and as much nearer to perfection as it becomes more free from air, it muſt be a perfect Conductor at the ſame time that it becomes a perfect vacuum, in which caſe electric attraction or repulſion cannot take place amongſt bodies incloſed in it; for, according to every notion we have of Electricity, thoſe motions indicate or are the conſequence of the intervening ſpace in ſome meaſure obſtructing the free paſſage of the electric fluid. And if the perfect vacuum is a perfect Non-conductor, then neither electric attraction nor repulſion can happen in it.

EXPERIMENT IV.

In my former experiments having always obſerved the electric light in the receiver of the air-pump, even when the air was rarefied to the utmoſt power of that machine, I thought proper to repeat that experiment with receivers of various ſizes; and accordingly have uſed receivers of above two feet in height, and ſome of as large a diameter as the plate of the pump could admit, which is about fourteen inches, but the light in it was always viſible, only with different colours in different degrees of exhauſtion, and always more diffuſed and at the ſame time leſs denſe when the air was more rarefied, which ſeems to render probable, that, when the air is quite removed from any ſpace, the electric light is no longer viſible in it, as it muſt have been the caſe with the experiment of Mr. WALSH's double barometer; for it is a maxim very well eſtabliſhed in Electricity, that the electric light is only viſible when the electric fluid, in paſſing from one body to another, meets with ſome oppoſition in its way; and according to this propoſition, when the air is entirely removed from a

given receiver, the electric fluid passing through that receiver cannot shew any light, because it meets with no opposition; but this will not account for the receiver ever becoming a Non-conductor.

Having just mentioned, that according as the air is more and more rarefied in a receiver, so the electric light becomes gradually more faint, it will be proper to add, that the electric light is more diffused and less bright in an exhausted receiver than in air: thus, when the receiver is not exhausted, the discharge of a jar through some part of it will appear like a small globule exceedingly bright, but when the receiver is exhausted, the discharge of the same jar will fill the whole receiver with a very faint light; whereas some persons, by seeing the whole receiver illuminated, are apt to say that the light of Electricity is rendered stronger and greater by the exhaustion.

EXPERIMENT V.

It is mentioned by Mr. NAIRNE, in the 67th vol. of the Philos. Trans. that having

put a piece of leather, just as it comes from the leather-sellers, into the receiver of an air-pump, and afterwards having rarefied the air in it one hundred and forty-eight times, the electric light appeared very faint in it; whereas, without the leather, and even when the air was much more rarefied, the light of the electric fluid, when made to pass through the receiver, was much more apparent. In consequence of this observation, I suspected that a little moisture in the receiver, or some other effluvia of substances, might perhaps prevent the appearance of the electric light in rarefied air, and with this view I began to put various substances successively into the receiver, and after rarefying the air by working the pump, some electric fluid was made to pass through the receiver.

When a piece of moist leather was put into the receiver the air could not be rarefied above one hundred times, and the electric light appeared divided into a great many branches; though at the same time another sort of faint light filled up the whole cavity of the receiver,.

When a linen rag, moistened with a mix-

ture of ſpirit of wine and water, was put into the receiver, the pump could not exhauſt above forty times, and the light of Electricity appeared divided into many branches.

A wine-glaſs full of olive oil placed under the receiver, prevented very little the exhauſtion of the pump, the air being rarefied above four hundred times. The electric light appeared exactly as it uſually does in the ſame degree of rarefaction when no oil is under the receiver, *viz.* a uniform faint light inclining to purple or red.

Concentrated vitriolic acid placed in a glaſs under the receiver, produced no particular effect. As for the other mineral acids, they were not tried, becauſe, being volatile, they would have damaged the pump.

Dry ſolids, that had a conſiderable ſmell, as ſulphur, aromatic woods previouſly made very dry, and ſome reſins, produced no particular effect, any more than ſome of them prevented a very great degree of exhauſtion, owing to ſome moiſture which ſtill adhered to them.

From these experiments it appears, first, that in the utmost rarefaction that can be effected by the best air-pump, which amounts to about one thousand, both the electric light and the electric attraction, though very weak, are still observable; but, secondly, that the attraction and repulsion of Electricity become weaker in proportion as the air is more rarefied, and in the same manner the intensity of the light is gradually diminished. Now by reasoning on this analogy we may conclude, that both the attraction and the light will cease in a perfect absence of air; but this will never account for this perfect vacuum ever becoming a Non-conductor of Electricity; for since the electric fluid is very elastic, and expands itself with more and more freedom in proportion as the resistance of the air is removed, it seems unnatural that it should be incapable of pervading a perfect vacuum: however, the fact seems to be fully ascertained by Mr. WALSH and Mr. MORGAN, and the only thing that remains to be done is to investigate the cause of so remarkable a property.

PART V.

THE PRACTICE OF MEDICAL ELECTRICITY.

CHAP. I.

General Remarks relating to Medical Electricity.

THE wonderful effects of that unknown cause generally named Electricity, ſoon after the diſcovery of the electrical machines, were applied as a remedy for various diſorders incident to the human body. The firſt hints of this application, ſeem to have been ſuggeſted by obſerving the effects produced upon thoſe perſons that were electrified for curioſity; who being generally afraid of that extraordinary power, attributed entirely to it all thoſe effects, which might in great meaſure have been attributed to fear and apprehenſion: ſuch were an increaſed perſpiration, heat, increaſe of pulſation, &c. The number of patients that were electrified at that time is prodigious, and the pretended cures effected

effected by it were wonderful indeed. Accounts of those miracles performed by Electricity, were published in various parts of Europe, together with the methods of electrifying the patients; to which were added, such theories as, allowance being made for the infancy of Electricity at that time, would seem impossible ever to have been proposed to the public. Those theories were usually enforced by the account of experiments, which often proved false upon examination *. Indeed, if electrical machines could not be procured at present, we could hardly entertain any doubt concerning the veracity of those accounts, which had all the appearance of authenticity. But at present a much better acquaintance with the science of Electricity, than philosophers had about thirty or forty years ago, and less faith in the accounts of the generality of those persons, whose interest it is to promote the use of Electricity in medicine; has pointed out the effects of that power upon the human body, in various circumstances, and has

* The medicated cylinders for electrical machines, are a remarkable instance of this kind. See Dr. PRIESTLEY's History of Electricity.

shewn

ſhewn how far we may confide in it; eſtabliſhing, upon indiſputable facts, that the power of Electricity is neither that admirable panacea it was conſidered by ſome fanatical and intereſted perſons, nor ſo uſeleſs an application as others have aſſerted; but that, when properly managed, it is an harmleſs remedy, which ſometimes inſtantaneouſly removes divers complaints, generally relieves, and often perfectly cures various diſorders, ſome of which could not be removed by the utmoſt endeavours of phyſicians and ſurgeons.

When the firſt rumour occaſioned in Europe by the accounts of pretended, and of a few real wonders, performed by means of Electricity, had in ſome meaſure ſubſided, many creditable and experienced phyſicians, who, juſtly conſidering it as their duty, had undertaken to examine the power of this new remedy, publiſhed ſome unſucceſsful applications of Electricity in divers diſeaſes; in which caſes, they had not only preſcribed the electrization, but the operation had been performed either by themſelves, or under their inſpection. Theſe publications

gave

gave a new turn to the reputation of medical Electricity; and since that time, the generality of physicians and surgeons had not the least regard for its medical application; so that the practitioners of it were rather considered as fanatics and impostors. However, an attentive examination of this subject, after several trials, and after overcoming in great measure the rooted prejudice amongst physicians, began to establish anew the reputation of medical Electricity; and shewed that many applications of Electricity, published in the above-mentioned accounts, had proved unsuccessful, because the operation was not managed properly; so that it had been the abuse, and not the use of Electricity, that had proved unsuccessful, and in some cases even detrimental; for at that time, strong shocks and strong sparks were generally administered, which a long series of experiments and observations has proved to be generally useless or hurtful. Mr. LOVET, who practised medical Electricity for a long time, was, as far as I know, the first who protested against the use of strong shocks; and in an essay of his, intitled, *Subtil Medium proved,* asserts,

aſſerts, that the ſhocks to be uſed in medical Electricity ſhould be very ſmall; by which treatment he hardly ever failed of curing, or at leaſt relieving his patients.

Electricity, different from other phyſical applications, requires rather a nicety of operation than a thorough knowledge of the diſeaſe. That it is poſſible to apply Electricity properly, without a juſt knowledge of the diſorder, may ſeem a paradox; but it will be preſently ſhewn, that to electrify a ſound part of the body together with the diſeaſed one, is by no means prejudicial, and that the degree of electrization muſt be regulated rather by the feeling of the patient, than by the ſpecies of diſorder; from whence it muſt follow, that the application of medical Electricity may be properly managed even with a ſuperficial knowledge of the diſorder. It muſt, however, be confeſſed, that farther experience may poſſibly ſhew much eaſier and more certain methods of applying it differently for different diſeaſes; and therefore it is more likely that medical Electricity will receive improvements in the hands of ſkilful phyſicians

physicians or surgeons, than when managed, by ignorant persons, whose success is entirely trusted to chance.

The superiority of Electricity over other remedies, in many cases, may appear from considering, that medicines in general cannot always be confined to a particular part of the body, and to let them pass through other parts is often dangerous, for which reason they cannot be used; besides, after that those medicines have exerted their required power, they are with great difficulty, if at all, separated from the body. But it is of no consequence whether the power of Electricity passes through this or that other part of the body in order to come at the seat of the disease; and after having exerted its action, it is instantly dispersed: hence it appears why Electricity has often cured such obstinate disorders as have not yielded to any other treatment.

Having in the ninth Chapter of Part I. given a summary view of the theory of Electricity, I shall here only mention a few hints, which may promote the investi-

gation of the action of the electric fluid, especially relating to its chymical action; *viz.* if it adds any principle to thoſe parts through which it paſſes, as an acid, an alkali, the inflammable principle, &c.—The obſervations relating to this point are, firſt, that when any part of the body has been expoſed to the ſtream of electric fluid, it acquires a ſulphurous, or rather a phoſphoric ſmell, which it retains for a conſiderable time. Secondly, when the ſtream of electric fluid, iſſuing from a point, is directed towards the palate, a kind of acid taſte is perceived. Now this ſmell and taſte indicate, that the electric fluid either alters the parts of the body, upon which it excites thoſe ſenſations, or that it carries along with itſelf ſome other principle, which may perhaps be ſeparated from thoſe ſubſtances, through which this fluid paſſes, previous to its impinging upon the body. — Whether thoſe effects may be increaſed, diminiſhed, or turned to any uſe, and alſo whether they are quite indifferent with reſpect to medical Electricity, are matters that require farther experiments and conſiderations; for nothing certain has been yet determined reſpecting them.

In

In various experiments, when the electric spark is taken in air, or other fluids, especially in the tincture of certain flowers, it shews effects similar to those, which the inflammable principle, or an acid, produces upon those fluids *. These experiments have induced various persons to suppose, that the electric fluid is phlogiston, or an acid, or else a compound of both. But, considering that in those cases the action of the electric fluid as an acid, or as phlogiston, is exceedingly small; and also considering the violence with which it passes through the substance of bodies, the surface of which it generally burns or melts in a small degree; it seems more natural to suspect, that the above-mentioned effects are produced by that quantity of inflammable or acid principle, which the violent passage and escape of the electric fluid detaches from other bodies, rather than to consider the electric fluid itself to be an acid, or the inflammable principle; which seems to be very unlikely on various other accounts.

* See the last four experiments of the Third Part.

A book entitled *De l'electricité du Corps humain, dans l'etat de santé et de maladie, par l'Abbé Bertholon,* was publiſhed a few years ago in France. In this work, the author, conſidering the uſual Electricity of the atmoſphere, imagines that the human body continually abſorbs that Electricity from the air, and that this abſorption is made through the pores of the ſkin, as well as through the lungs in the uſual act of reſpiration; and, as the quantity of air which enters into the lungs of a man in the courſe of one day, is by the author eſtimated to about 1,152,000 cubic inches, he thence deduces, that the quantity of Electricity thus abſorbed by the human body is aſtoniſhingly great. The author ſucceſſively examines the influence of this abſorbed Electricity upon the functions of the body, *viz.* upon muſcular motion, upon the circulation of the blood, upon reſpiration, digeſtion, ſecretions, and even upon the morals of men. He alſo takes notice of the Electricity of ſeveral animals, and even mentions ſome qualities of the air, or of the aliments, which are proper to augment or diminiſh the Electricity of the human body. In the

application of thoſe principles to medicine, the author gives a table of diſeaſes, arranged in ſpecies and genera, and comprehended under ten claſſes; which diſeaſes, as he ſays, are occaſioned in great meaſure, if not wholly, by Electricity, either poſitive or negative; and which may be cured by one or the other of thoſe two electrical powers, according as the ſigns concomitant the diſeaſe may indicate.

The Abbé Bertholon alſo treats of the influence of atmoſpherical Electricity upon the number of births or deaths, and other things of the like nature.

A perſon verſed in Electricity, conſidering that the air next to the body of a man, in his uſual mode of living, is ſeldom if ever ſenſibly electrified, and alſo that the human body is a ready conductor of Electricity, beſides many other obvious conſiderations, muſt naturally ſuſpect that the author of the above-mentioned work has indulged his fancy perhaps too much.

CHAP. II.

Directions for the practical Application of Electricity for the Cure of various Diseases.

OMITTING the description of the electrical machine, and the manner of preserving it in good order (which things are to be found in the first part of this work) I shall only observe, with respect to the electrical machine in general, that its size should not be so small as was thought sufficient some time ago, when the smallest machines were supposed to be sufficiently useful for the purpose. It is somewhat remarkable, that when a small power of Electricity is to be used, large machines should be recommended; whereas, a short time ago, strong shocks were administered, and small electrical machines were used; but it must be considered, that when shocks are given, very small electrical machines can charge a Leyden phial much stronger than required; but when the stream is used, which has lately been found to be far more efficacious, then the small machines are

moſtly uſeleſs. Probably the largeſt machines will not be found to afford a ſtream too ſtrong for medical purpoſes; but the uſeful ones, which do not require a great labour to be put in motion, and may furniſh a ſtream ſufficiently denſe, ſhould have the glaſs globe or cylinder about nine inches in diameter, which, with a proportionate Conductor, may uſually give ſparks about three inches long. Whether the rubber of theſe machines ſtands upon a glaſs pillar or not, *viz.* whether it may be occaſionally inſulated or not, ſeems to be immaterial with reſpect to medical Electricity: but as to have it ſituate upon a glaſs pillar is uſeful for electrical experiments in general, and perhaps it may be found hereafter, that negative electrization is beneficial in ſome diſorders; a perſon who is to chooſe a new electrical machine, may rather have the rubber fixed upon a glaſs pillar, than otherwiſe. Mr. NAIRN's new machine has every neceſſary advantage *.

With ſuch machines, the power of Electricity ſhould be ſo regulated, as to apply

* See vol. I. p. 165.

every

every degree of it with facility and readiness; beginning with a stream issuing out of a metal point, next using a wooden point, then small sparks, stronger sparks, and lastly small shocks. Every one of these methods may be increased or diminished considerably, by a proper management: thus, by turning the wheel of the machine swifter or slower, the stream of electric fluid may be regulated according as the circumstances may require. The sparks may also be made stronger or weaker, by taking them at a greater or less distance, and by turning the wheel swifter or slower; and so of the rest.

It is impossible to prescribe the exact degree of electrization that must be used for various disorders; for persons of different constitutions, although afflicted with the very same disease, require different degrees of electrization. Some persons are of so delicate and irritable a constitution, that the smallest sparks give them as much pain as shocks do others. On the contrary, some people can suffer pretty severe shocks without positive pain; and I have heard,

though never ſaw any, of perſons who were inſenſible of any electric power, even of conſiderably ſtrong ſhocks,

In reſpect to this important point, the operator muſt be certainly inſtructed by experience; however, in the beginning he may be aſſiſted by the two following rules. Firſt, he ſhould begin to adminiſter to his patients the very ſmalleſt degree of electric power, which he ought to continue for a few days, ſo as to obſerve whether it produces any good effect, which if it fails to do, he ſhould then increaſe the ſtrength of Electricity; and ſo proceed gradually till he finds the effectual method, which he ſhould follow without variation, till the patient is intirely cured. In ſhort, the operator ſhould always uſe the ſmalleſt degree of electric power, that is ſufficient for the purpoſe. A little practice will enable him to determine at once what degree of Electricity is required for his patient, without any uſeleſs attempts. Secondly, the degree of electrization to be adminiſtered, ſhould never exceed that which the patient can conveniently ſuffer;

8 experience

experience ſhewing, that when the application of any degree of Electricity is very diſagreeable to the patients, they very ſeldom mend.

The inſtruments which, beſides the electrical machine and its prime Conductor, are neceſſary for the adminiſtration of medical Electricity, may be reduced to three, *viz.* an electric jar, with Mr. LANE's electrometer; an inſulated chair, or an inſulated ſtool, upon which a common chair may be occaſionally ſet; and the directors *.

Thoſe inſtruments are delineated in the fifth plate. Fig. 1. repreſents the electric jar, with Mr. LANE's electrometer, and the manner in which the ſhocks are ſent through any particular part of the body. The ſurface of the jar, which is coated with tin-foil, ſhould be about four inches in diameter, and ſix inches high, which is equal to about ſeventy-three

* Various other inſtruments uſeful in medical electricity, are deſcribed in divers books, but thoſe mentioned above are ſufficient to anſwer every required purpoſe.

ſquare inches. The braſs wire, which paſſes through the covering of the jar and touches the inſide coating, has a braſs ball, F, to which the electrometer F D E is faſtened; and proceeding a little farther up, terminates in another braſs ball B, which ſhould be ſo high as to touch the prime Conductor A, which is ſuppoſed to ſtand before the electrical machine. The electrometer conſiſts in a glaſs ſtick F D, cemented to two braſs caps F and D; from the latter of which a ſtrong perpendicular braſs wire proceeds, the extremity of which comes as high as the center of the ball B, and is furniſhed with an horizontal ſpring ſocket, through which the wire C E, having the braſs ball C at one end, and the open ring E at the other, may be ſlided backwards and forwards, ſo as to ſet the braſs ball C at any required diſtance from the ball B. This diſtance, at moſt, needs not be greater than half an inch; hence the electrometer may be made very ſmall. Sometimes ſmall diviſions are marked upon the wire C E, which ſerve to ſet the balls B and C at a given diſtance from one another, with more readineſs and preciſion. Now ſuppoſe,

poſe that the jar is ſet contiguous to the prime Conductor, that is, with the ball B touching the Conductor; that the ball C be ſet at one-tenth of an inch diſtance from the ball B; and that, by means of wire, a conducting communication be formed from E to the outſide coating of the jar, as is repreſented by the dotted line in the figure. In this caſe, if the electrical machine be put in motion, the jar will be charged; and when the charge is ſo high as that the electric fluid accumulated within the jar can leap from the ball B to C, which we have ſuppoſed to be one-tenth of an inch aſunder, the diſcharge will happen, a ſpark appearing between the ſaid balls, and the ſhock paſſes through the wire repreſented by the dotted line; for the part F D of the electrometer being of glaſs, generally covered with ſealing-wax, is impervious to Electricity, conſequently the electric fluid has no other way through which it can paſs from the inſide to the outſide of the glaſs jar. When the ſhocks are to be given with this apparatus to any particular part of the body, for inſtance, to the arm, then, inſtead of the dotted line repreſenting a wire, which muſt

now

now be ſuppoſed as not exiſting in the figure, two ſlender and pliable wires, E L, I L, are to be faſtened, one to the open ring E of the electrometer, and the other to the braſs hook I of the ſtand H I, which communicates with the outſide coating of the jar *. The other extremities of the ſaid wires are faſtened each to the braſs wire L, and L, of the directors K L, K L. Each of thoſe inſtruments, juſtly called *directors*, conſiſts of a knobbed braſs wire L, which by means of a braſs cap is cemented to the glaſs handle K. The operator, holding them by the extremity of the glaſs handle, brings their balls into contact with the extremities of that part of the body of the patient through which he deſires to ſend the ſhock. The management and convenience of this apparatus are eaſily comprehended by inſpecting the figure; for when the machine is in motion, and the apparatus, &c. is ſituate as in the figure, the diſcharge of the jar muſt be

* If the jar has not the ſtand H I, the extremity I of the wire I L may be ſimply reſted under, or may be tied round it. In ſhort, it muſt be put in contact with the outſide coating of the jar, in any convenient manner.

evidently made through that part of the patient's arm, which lies between the knobs of the directors; and the operator, whilst an assistant keeps the machine in motion, has nothing more to do, than to hold the knobs of the directors to the extremities of the arm, or to any other part of the body that is required to be thus electrified; always taking care that the two wires E L, I L, do not touch each other, because in that case the shock will not pass through that part of the body which is required to be electrified. Thus any number of shocks, precisely of the same strength, may be given, without altering any part of the apparatus, or having any farther trouble; and when the strength of the shocks is required to be diminished or increased, it is only necessary to diminish or augment the distance between the balls B C, which is done by slipping the wire C E forwards or backwards through the spring socket that holds it.

It is almost superfluous to mention, that when shocks are administered, it is immaterial whether the patient stands upon the ground,

ground, upon the insulating stool, or in any other situation whatever. It is neither always necessary to remove the cloaths from the part that must be electrified, in order to let the knobs of the directors touch the skin; for, except the coverings be too many and too thick, in which case part of them at least should be removed, the shocks will go through them very easily, especially if the knobs of the directors be pressed a little upon the part.

In the course of this essay we shall describe the strength of the shocks by the distance between the balls B and C of the electrometer, which we shall express by parts of an inch; supposing that the said electrometer is fixed upon such a jar as we have described above, *viz.* whose coated part, besides the bottom, may be equal to about 73 square inches, and whose glass is moderately thin; for a larger or thicker jar with the same electrometer, set at the same distance, will produce a much different effect, as must be obvious to any person a little acquainted with the science of Electricity.

Besides

Besides the directors mentioned above, there are other kinds of directors, which serve for throwing the stream of electric fluid, and other similar purposes. These are delineated in fig. 2. and 3. The director D, in fig. 2. is much like those described above, excepting only that its wire is bent, and instead of having any ball, it terminates in a point, to which is affixed a piece of wood about one inch or one inch and a half long, pointed at one end, though not very sharp, and having a hole at the other *. The operator should have by him various such wooden pieces, of different lengths and thickness, as E E, so as to shift them according as circumstances may require; for sometimes the wooden pieces are too dry or too damp, or the machine is in bad order, &c. in which cases the stream of electric fluid would be either too strong or too weak, if the same wooden point was always used. The wood proper to make these pointed pieces should be rather of a soft kind, than hard, as box wood and lignum vitæ are.

* These directors are sometimes made with very slender and annealed wires, so that they may be bent in every required direction.

In order to throw the electric fluid with this director, let a wire B, proceeding from the prime Conductor A, fig. 2. be fastened to the wire of the director D E, which the operator must hold by the extremity of the glass handle, and must manage it so as to keep the wooden point at about one or two inches distance from the body of the patient *. This distance, however, must be regulated according to the constitution of the patient, the strength of the electrical machine, and other circumstances, which will be suggested by a little practice. The electric fluid issuing from the wooden point, has a power which is intermediate between that of the stream proceeding from a metal point, and the power of the sparks; but yet it is in general the most efficacious method of electrization, and therefore no pains should be spared in order to administer it in the best possible manner. This stream consists of a vast number of exceedingly small sparks, accompanied with a little

* When this or any other operation is performed, the electric jar, and in general any instrument not actually necessary, must be removed from the prime Conductor, and even from the table if that be rather small.

wind, which gently irritates the part electrified, and gives a warmth which proves very agreeable to the patients. Sometimes, when the machine is very powerful, and the wooden point is ſhort or ſplit, a very full and pungent ſpark iſſues from it; which is a very diſagreeable accident, eſpecially when the part electrified is very delicate. In order to avoid this inconvenience, the operator ſhould firſt try the goodneſs of the point, before he begins the operation; which he may do by throwing the ſtream upon his own hand or face.

The above-mentioned method of electrifying, gentle as it may appear, will nevertheleſs be found too ſtrong for ſome perſons, eſpecially when uſed for open ſores upon delicate parts; in which caſes the wooden point muſt be removed, and the electric fluid muſt be ſimply thrown from the metal point of the director, which muſt now be kept at a greater diſtance than when the wooden piece was upon it. The electric fluid iſſuing out of this pointed wire of the director, occaſions only a gentle wind upon the part towards which it

is directed, and is far from being disagreeable even to the most delicate constitution.

It might be naturally suspected, that so gentle and nearly insensible a treatment could hardly be of any efficacy; but my reader may be assured, that to my certain knowledge, deduced from the practice of persons who have had long experience in this subject, this method of electrization, *viz.* the throwing the fluid with a metal point, has often mitigated pains, and cured obstinate and dangerous diseases, which could not be removed by any other remedy that was tried.

In general this treatment, upon delicate nervous constitutions, is as efficacious as the other, *viz.* the throwing the fluid with a wooden point, is to ordinary constitutions. In several cases, especially of open sores, the electric fluid issuing out of a wooden point has constantly increased the pain, and even enlarged the sore; whereas the fluid issuing out of the metal point, has effectually diminished both.

The ſtream iſſuing out of a wooden point may be directed towards the eyes of the patient, without any apprehenſion of hurting him; in which caſe the operator ſhould keep the eye-lid open with one hand. Indeed there might be ſome caſes, though I ſeldom heard of any, in which this treatment may be thought to be too ſtrong; then the metal point only may be uſed.

The ſtream iſſuing both out of the wooden and of the metal point, acts even through the cloaths, if they are not too thick; hence it may be uſed without incommoding the patient: but when it is convenient to uncover the part which is to be electrified, it is much preferable to direct the fluid immediately upon the ſkin.

In this operation, the practitioner muſt mind to ſhift the point of the director about, ſo that the ſtream of electric fluid may be directed not only towards the affected part, but alſo to the places about it; alternately returning to the ſame place, and moſtly inſiſting upon the part principally affected.

The patient in this operation may also ſtand in every ſituation that may happen to be more convenient to him.

When more proper inſtruments cannot be had, directors may be made by ſticking large pins upon ſticks of ſealing-wax, as is repreſented at K, fig. 2.

Sometimes the wire B, which forms the communication between the prime Conductor and the director, throws a conſiderable quantity of electric fluid into the air, which weakens the ſtream iſſuing from the point. In order to remedy this inconvenience, I contrived a conducting wire, which being uſed by ſome of my friends, who practiſe Medical Electricity, has been found to anſwer very well the purpoſe of not diſſipating the electric fluid. This conducting communication is formed of a ſilver, gold, or copper thread, ſuch as are uſed for laces, which conſiſt of a ſmall lamina of metal twiſted round a ſilk or linen thread. This metal thread, or two of them, muſt be involved in a ſilk ribbon, which is coiled and ſewed very tight upon it, leaving only a loop of

of the metallic thread uncovered at each extremity, one of which is to be faſtened to the prime Conductor, and the other to the wire of the director. See G H, fig. 2.

This ſort of conducting communication, beſides its preventing the diſſipation of the electric fluid, is much more pliable than the ſtiff wire commonly uſed, and conſequently may be managed more eaſily. It may be alſo uſed inſtead of the wires E L, I L, fig. 1. in the operation of giving ſhocks.

Two other directors different from the above-mentioned, are delineated in fig. 3. Their uſe is to draw ſparks from the inſide of the ear in caſes of deafneſs, pains, &c. and alſo from the teeth or other internal parts of the mouth. The director B H conſiſts of a glaſs tube A B, about ſix inches long, and open at both ends; the diameter of which may be about one-tenth of an inch, and the ſubſtance of the glaſs rather thick. A cork is thruſted into one end of this tube, through which a wire paſſes; one extremity of which is cut blunt and ſmooth,

and comes within one or two-tenths of an inch ſhorter than the end B of the tube. The other extremity H of the wire, is furniſhed with a ſmall metal ball.—Long pins, ſuch as the ladies uſe for their hats, anſwer this purpoſe exceedingly well, when their points are filed off. The other director C D differs from that juſt deſcribed, in being only bent a little, for the conveniency of adapting it more eaſily to ſome parts within the mouth.

When theſe directors are uſed, the patient muſt be ſituated upon an inſulating ſtool, *viz.* a ſtool furniſhed with glaſs feet, upon which a chair may be placed. Then a communication muſt be formed between the prime Conductor and the body of the patient, by means of any ſort of wire, eſpecially that repreſented by G H, fig. 2. or by the patient only touching the prime Conductor with his hand. In this caſe, it is eaſy to conceive that the patient becomes part of the prime Conductor; and if any blunt conducting body be brought near him, when the machine is in action, a ſpark is obtained from him in the ſame

manner

manner as when the ſame blunt body is preſented to the prime Conductor itſelf. Every thing being thus far prepared, the operator holding the director A B or C D by its middle E or F with one of his hands, muſt bring the extremity B or D of the tube into contact, or nearly ſo, with the inſide of the ear, mouth, &c. of the patient, as occaſion may require; and muſt bring the knuckle of a finger of his other hand within a ſmall diſtance of the ſmall knob H or G of the director, which will extract ſmall ſparks from it, and at the ſame time the like ſparks will happen between the other extremity of the wire within the tube, and the part of the patient's body towards which the inſtrument is directed.

This is an excellent method to be practiſed in caſes of deafneſſes, pains in the ears, tooth-achs, ſwellings within the mouth, &c. eſpecially becauſe it may be increaſed or diminiſhed at pleaſure; *viz.* by drawing the wire G or H more or leſs from the extremity B or D of the tube, the ſtrength of the ſparks may be increaſed or diminiſhed.

Not only ſparks, but alſo the ſtream of electric fluid may be drawn with thoſe directors. This is done by bringing (inſtead of the knuckle) a pointed piece of wood near the ſmall knob H or G of the director; every thing elſe being diſpoſed as already directed.

When ſparks are required to be drawn from any part of the body, the patient muſt be ſituated upon an inſulating ſtool, and muſt be connected with the prime Conductor in the manner directed above; then the operator bringing the knuckle of one of his fingers, or the knob of a braſs wire like K L, fig. 3. oppoſite to the affected part, will draw the ſparks from it; which ſparks will paſs very eaſily through the cloaths, if they are not very thick. When the knobbed wire K L is uſed to draw ſparks with, the operator muſt hold it by the extremity K, and preſent the knob L, &c.: but it may alſo be uſed to draw the fluid ſilently, in which caſe the point K muſt be preſented, and the knob L muſt be held by the hand of the operator. Here a wooden point may alſo be uſed,

ufed, *viz.* by affixing it to the point K of the wire; which method anfwers as well as that of throwing the electric fluid by means of a wooden or metal point, with the director D of fig. 2. defcribed in the preceding pages.

Sometimes it is required to take fparks from fuch parts as are covered with thick cloaths, and the patient is rather unwilling to uncover. In this cafe the beft method is to fituate the patient upon the infulating ftool in contact with the prime Conductor, then to bring the knob of a director, like one of thofe delineated in fig. 1. in contact with the cloaths over the part required to be electrified; whilft the operator, holding the inftrument by the extremity of its glafs handle with one of his hands, brings the knuckle of one of his fingers, or the knob of the wire K L, fig. 3. pretty near the brafs cap of the director, fo as to draw ftrong fparks from it; the force of which will be felt very fmartly upon the part of the patient's body; for at the fame time fparks will happen there acrofs the cloaths, *viz.* between the part of the body of the

patient, and the knob of the director, which, for better ſecurity, ſhould be preſſed a little upon the cloaths.

In all theſe caſes when the electric fluid, either in a ſtream or under the form of ſparks and ſhocks, is to be forced acroſs the cloaths, it is ſuppoſed that no metallic ornaments ſhould be interpoſed, as gold or ſilver lace, long pins, and the like; for then the effects will vary conſiderably, according to the different circumſtances.

There is another method of electrifying a diſeaſed part of the body, which cannot properly be called drawing ſparks, though it comes very near to it. This manner of electrifying is effected in the following way; The patient is ſituated upon the inſulating ſtool, and is made to communicate with the prime Conductor; then a dry and warm flannel, either ſingle or double, according as it may be occaſionally thought more proper, is ſpread upon the naked part that muſt be electrified, and over this flannel the operator muſt put the knob L of the wire K L, fig. 3. quite into con-

tact with the flannel, whilst he holds it by the other extremity K. Now when the machine is in action, the knob L of the wire must be shifted very quick and nimbly from place to place over the flannel; in which case a vast number of exceedingly small sparks will be drawn across the flannel; which generally bring an agreeable warmth on the part, and prove very beneficial to the patient, at the same time that they do not cause any very disagreeable sensation. In cases of paralytic limbs, rheumatism, spreading pains, coldness of any particular part, &c. this treatment is of singular benefit. In the following pages we shall call it *The method of drawing sparks through a piece of flannel*, or simply, *to draw sparks through flannel.*

As for the insulating chair, it is almost needless to give any particular directions concerning its construction; it being nothing more than a common wooden chair set upon an insulating stool; or, as some persons choose to have it, the chair itself is furnished with glass, instead of wooden legs, which answers equally well. It is

requisite

requiſite that no ſharp metallic points be put upon this chair; and even its wooden ornaments ſhould be rather blunt than ſharp-edged; for points and edges in general diſſipate the electric fluid conſiderably, and conſequently weaken the power of the machine. The glaſs feet ſhould be at leaſt eight inches high; and, that they may inſulate the better, eſpecially in damp weather, they ſhould be covered with ſealing-wax or good amber varniſh. In the conſtruction of this chair, a place ſhould be always provided, whereupon the patient may reſt his feet; the want of which is very diſagreeable, becauſe it is abſolutely neceſſary that the feet do not touch the floor.—When only a common chair is to be occaſionally ſet upon an inſulating ſtool, the latter ſhould be made ſomewhat larger than the former, ſo that part of it may project before the chair, upon which the perſon to be electrified may reſt his feet.

After the deſcription of the inſtruments neceſſary for the adminiſtration of Medical Electricity, I ſhall collect together ſome practical rules, which may ſerve for a guide

to those practitioners, who have not yet been sufficiently instructed by their own experience.

General Rules for Practice.

I. It should be attentively observed to employ the smallest force of Electricity, that is sufficient to remove or to alleviate any disorder; thus the shocks should never be used when the cure may be effected by sparks; the sparks should be avoided when the required effect can be obtained by only drawing the fluid with a wooden point; and even this last treatment ought to be omitted, when the fluid drawn by means of a metal point, may be thought sufficient. The difficulty consists in distinguishing the proper strength of electric power that is required for a given disorder, the sex and constitution of the patient being considered. In regard to this point, it is impossible to give any exact and invariable rules; the circumstances being of such a nature, and so various, that long experience, and a strict attention to every particular phenomenon, are the only means

by

by which proper instructions may be received. The surest rule, as we observed above, that can be given relating to this particular, is to begin by the most gentle treatment; at least such, that, considering the constitution of the patient, may be thought rather weak than strong. When this gentle treatment has been found ineffectual for a few days, which is denoted by the disease not abating, and the application of Electricity not causing any warmth, or other promising phenomenon upon the part electrized; then the operator may gradually increase the force of Electricity till he finds the proper degree of it.

II. In judging of cases proper to be electrified, experience shows, that in general, all kinds of obstructions, whether of motion, of circulation, or of secretion, are very often removed or alleviated by Electricity. The same may also be said of nervous disorders; both which include a great variety of diseases. The application of Electricity has seldom intirely cured diseases of a long standing, although it generally relieves them. To persons afflicted with the

the venereal diſeaſe, or to pregnant women, electrization has been thought to be pernicious; but my reader may be aſſured, that even in thoſe caſes it may be uſed without fear, if it be judiciouſly managed. When pregnant women are to be electrified for any diſorder, the ſhocks ſhould be abſolutely forbidden; and even when the other more gentle treatments are uſed, a conſtant attention ſhould be given to any phenomenon that may appear in the courſe of the electrization; the method of which ſhould be increaſed, diminiſhed, or ſuſpended, according as circumſtances may indicate. As for the venereal diſeaſe, it will be hinted, in the courſe of this work, in what manner, and in which caſes, Electricity may be applied.

III. In caſes of gathering tumours, the beſt method is to draw the fluid by means of a wooden point, or, if that prove painful, by a metal point. Sparks in theſe caſes, and alſo ſhocks, are often hurtful. In ſtiffneſſes, paralyſies, and rheumatiſm, ſmall ſparks, eſpecially through a double flannel, and alſo very ſmall ſhocks (at moſt of one-

tenth

tenth of an inch) may be uſed. Stronger ſhocks may be ſometimes, though ſeldom, adminiſtered for a violent tooth-ach, and for ſome internal ſpaſm of no long ſtanding.

IV. When any limb of the body is deprived of motion, it muſt be obſerved, that the privation of motion is not always occaſioned by a contraction of the muſcles; but that it is often the effect of relaxation; thus, for inſtance, if the hand is bent inwardly, and the patient has no power of ſtraightening it, the cauſe of it may be a weakneſs of the outward muſcles, as well as a contraction of the inward ones. In ſuch caſes, as it is often difficult even for good anatomiſts to diſcover the real cauſe, the ſureſt method is to electrify not only thoſe muſcles which are ſuppoſed to be contracted, but alſo their antagoniſts; for to electrify a ſound muſcle is by no means hurtful.

V. When the ſtream of electric fluid is thrown either with a wooden or metal point, the length of the operation ſhould be from three to ten minutes, more or

leſs,

lefs, according as occafion may require. When fhocks are adminiftered, their greateft number fhould not exceed a dozen or fourteen, except when they are to be given to the whole body in different directions. The number of fparks, when they are ufed, may generally exceed the number of fhocks mentioned above.

VI. Laftly, it may be of ufe to mention, that when children muft be electrified upon the infulating chair, as it is difficult to let them remain quiet, the moft convenient method is, to let another perfon fit in the infulating chair, and to hold the child whilft the operator is electrifying him.

Having thus comprifed into a few general rules, the method of applying Electricity with fafety, we fhall next defcribe the particular treatment, which has been found more expeditious and beneficial in diforders of various fpecies; and fhall laftly add fome authentic cafes, which will ferve as examples for the generality of practitioners.

The minute detail of the apparatus ne-

ceſſary for Medical Electricity, and ſeveral of the obſervations made on the particular uſe of it, may be thought more than neceſſary for a perſon who is maſter of the preceding part of this work; but as it is more than probable, that many perſons will conſult this book merely for the ſake of the medical part, I thought proper to prevent any poſſible miſtake, which conciſeneſs may produce.

CHAP. III.

Containing the particular Method of adminiſtring Electricity for various Diſeaſes, and the Account of ſome authentic Caſes.

THE account of a few ſucceſsful caſes in Medical Electricity, as well as in any other branch of phyſic, does by no means eſtabliſh the reputation of the treatment, when a vaſt number of unſucceſsful trials are concealed from the eyes of the public. The variety of temperaments obſervable in the human ſpecies, and the coincidence of circumſtances, is ſuch, that ſometimes very obſtinate diſorders ſeem to be cured by very trifling applications. The phyſicians,

physicians, however, justly neglect those kinds of treatment, because they have actually failed in a great many cases seemingly of the same nature.

In order, therefore, to give a proper estimate of the efficacy of a remedy, it is necessary to shew the proportion between the successful and the unsuccessful trials; without being amazed at one case, and neglecting many others.

Agreeably to this observation, the reader will find in the following pages, an estimate of the effects of Electricity applied as a remedy for various disorders. This estimate has been deduced from the cases which are hitherto come to my notice, and is therefore likely to receive much alteration and amendment by better information, and future observations.

Rheumatic disorders, even of long standing, are relieved, and generally quite cured, by only drawing the electric fluid with a wooden point from the part, or by drawing sparks through flannel. The operation should be continued for about four

or five minutes, repeating it once or twice every day.

Deafneſs, except when it is occaſioned by obliteration, or other improper configuration of the parts, is either intirely or partly cured by drawing the ſparks from the ear with the glaſs-tube-director, or by drawing the fluid with a wooden point. Sometimes it is not improper to ſend exceedingly ſmall ſhocks (for inſtance, of one-thirtieth of an inch) from one ear to the other.—It has been conſtantly obſerved, that whenever the ear is electrified, the diſcharge of the wax is conſiderably promoted.

The tooth-ach, occaſioned by cold, rheumatiſm, or inflammation, is generally relieved by drawing the electric fluid with a point, immediately from the part, and alſo externally from the face. But when the body of the tooth is affected, electrization is of no uſe; for it ſeldom or never relieves the diſorder, and ſometimes increaſes the pain to a prodigious degree.

Swellings in general, which do not contain any *matter*, are moſtly cured by drawing

drawing the electric fluid with a wooden point *. The operation ſhould be continued for three or four minutes every day.

Inflammations of every ſort are generally relieved by a very gentle electrization.

In *inflammations of the eyes*, the throwing of the electric fluid by means of a wooden point, is conſtantly attended with great benefit: the pain being quickly abated, and the inflammation being generally diſſipated in a few days. In theſe caſes, the eye of the patient muſt be kept open, and care ſhould be taken not to bring the wooden point very near it. Sometimes it is ſufficient to throw the fluid with a metal point; for in theſe caſes, too great an irritation ſhould be always avoided. It is not neceſſary to continue this operation for three or four minutes without intermiſſion; but, after throwing the fluid for about half a minute, a ſhort time may be allowed to the patient to reſt, and to wipe

* It is very remarkable, that in ſome caſes of white ſwellings, quite cured by means of Electricity, even the bones and cartilages were in ſome meaſure disfigured.

his tears, which generally flow very copiously; then the operation may be continued again for another half minute, and so on for four or five times every day.

The *gutta serena* has been sometimes cured by electrization; but at the same time it must be confessed, that to my certain knowledge, Electricity has proved ineffectual in many such cases, in which it was administered for a long time, and with all possible attention. I do not know that ever any body was worsted by it. The best method of administring Electricity in such cases, is first to draw the electric fluid with a wooden point for a short time, and then to send about half a dozen shocks of one-twentieth of an inch from the back and lower part of the head to the forehead, very little above the eye.

A remarkable disease of the eyes was some time ago perfectly cured by electrization; it was an opacity of the vitreous humour. This seems to be the only case of the kind, to which Electricity was applied.

All

All the cafes of *fiftula lacrymalis*, as far as I am informed, that have been electrified by perfons of ability for a fufficient time, have been entirely cured. The method generally practifed, has been that of drawing the fluid with a wooden point, and to take very fmall fparks from the part. The operation may be continued for about three or four minutes every day. It is remarkable that in thofe cafes, after curing the fiftula lacrymalis, no other difeafe was occafioned by it, as blindnefs, inflammations, &c. by fuppreffing that difcharge.

Palfies are feldom perfectly cured by means of Electricity, efpecially when they are of long ftanding, and the intellect is affected; but they are generally relieved to a certain degree. The method of electrifying in thofe cafes, is to draw the fluid with a wooden point, and to draw fparks through flannel; or through the ufual coverings of the part, if they be not too thick. The operation may be continued for about five minutes *per* day.

Ulcers, or open fores of every kind, even

of a long ſtanding, are generally diſpoſed to heal by electrization. The general effects are a diminution of the inflammation, and at firſt a promotion of the diſcharge of properly formed matter; which diſcharge gradually leſſens, according as the limits of the ſore contract, till it is quite cured. In theſe caſes the gentleſt electrization muſt be uſed, in order to avoid too great an irritation, which is generally hurtful. To draw or throw the fluid with a wooden, or even with a metal point, for three or four minutes *per* day, is quite ſufficient.

Cutaneous eruptions have been ſucceſsfully treated with electrization; but in theſe caſes it muſt be obſerved, that if the wooden point is kept too near the ſkin, ſo as to cauſe any conſiderable irritation, the eruption will ſometimes be cauſed to ſpread more; but if the point be kept at about ſix inches diſtance, or farther, if the electrical machine be very powerful, the eruptions will be gradually diminiſhed, till they are quite cured. In this kind of diſeaſe, the immediate and general effect of the wooden point, is to occaſion a warmth about the

electrified part, which is always a ſign that the electrization is rightly adminiſtered.

The application of Electricity has perfectly cured various caſes of *St. Vitus's Dance*, or of that diſeaſe which is commonly called ſo; for it is the opinion of ſome learned phyſicians, that the real diſeaſe called St. Vitus's Dance, which formerly was more frequent than it is at preſent, is different from that which now goes under that name. In this diſeaſe, ſhocks of about one-tenth of an inch may be ſent through the body in various directions, and alſo ſparks may be taken. But if this treatment prove very diſagreeable to the patient, then the ſhocks muſt be leſſened, and even omitted: inſtead of which, ſome other more gentle applications muſt be ſubſtituted.

Scrophulous tumors, when they are juſt beginning, are generally cured by drawing the electric fluid with a wooden or metal point from the part. This is one of thoſe kinds of diſeaſes in which the action of Electricity requires particularly the aid of

other medicines, in order to effect a cure more eaſily; for ſcrophulous affections generally accompany a great laxity of the habit, and a general cachexy, which muſt be obviated by proper remedies.

In *cancers*, the pains only are moſtly alleviated by drawing the electric fluid with a wooden or metal point. I know of one caſe only, in which a moſt confirmed cancer of very long ſtanding, on the breaſt of a lady, has been much reduced in ſize. It is remarkable, that this patient was ſo far relieved by drawing the fluid with a metal point from the part, that the excruciating pains ſhe had ſuffered for many years, did almoſt intirely diſappear; and alſo, that when the electric fluid was drawn by means of a wooden point, the pains did rather increaſe. This perſon, when I heard of her laſt, was ſtill under the application of Electricity; and the cancer ſeemed not unlikely to be perfectly cured, although contrary to the expectations even of the judicious phyſician who electrified her, and who knows too well the nature of that dangerous diſeaſe.

Abſceſſes,

Abscesses, when they are in their beginning, and in general whenever there is any tendency to form matter, electrization disperses them. Lately, in a case in which matter was formed upon the hip, called the *lumbar abscess*, the disease was perfectly cured by means of Electricity. The *sciatica* has also been often cured by it. In all such cases, the electric fluid must be sent through the part by means of two directors applied to opposite parts, and in immediate contact either with the skin, or with the coverings, when these are very thin. It is very remarkable, that the mere passage of the electric fluid in this manner, is generally felt by the patients afflicted with those disorders, nearly as much as a small shock is felt by a person in good health. Sometimes a few shocks have been also given, but it seems more proper to omit them; because sometimes, instead of dispersing, they rather accelerate the formation of matter.

In cases of *pulmonary inflammations*, when they are in the beginning, electrization has sometimes been beneficial; but in confirmed diseases of the lungs, I do not know that

that it ever afforded any unqueſtionable benefit; however, it ſeems that in ſuch caſes the power of Electricity has been but ſeldom tried.

Nervous head-achs, even of a long ſtanding, are generally cured by electrization. For this diſeaſe, the electric fluid muſt be thrown with a wooden, and ſometimes even with a metal point, all round the head ſucceſſively. Sometimes exceedingly ſmall ſhocks have been adminiſtered; but theſe can ſeldom be uſed, becauſe the nerves of perſons ſubject to this diſeaſe are ſo very irritable, that the ſhocks, the ſparks, and ſometimes even the throwing the electric fluid with a wooden point kept very near the head, throws them into convulſions.

The application of Electricity has often been found beneficial in the *dropſy*, when juſt beginning, or rather in the tendency to a dropſy; but it has never been of any uſe in advanced dropſies. In ſuch caſes, the electric fluid is ſent through the part, in various directions, by means of two directors, and ſparks are alſo drawn acroſs

the

the flannel or the cloaths; keeping the metal rod in contract with them, and ſhifting it continually from place to place. This operation ſhould be continued at leaſt ten minutes, and ſhould be repeated once or twice a day.—Perhaps in thoſe caſes, a ſimple electrization, (*viz.* to inſulate the patient, and to connect him with the prime Conductor whilſt the machine is in action) continued for a conſiderable time, as an hour or two, would be more beneficial.

The *gout*, extraordinary as it may appear, has been cured by means of Electricity, in various inſtances. The pain has been generally mitigated, and ſometimes the diſeaſe has been removed ſo effectually as not to return again. In thoſe caſes, the electric fluid has been thrown by means of a wooden point, although ſometimes, when the pain was too great, a metal point only has been uſed.

Agues very ſeldom fail of being cured by Electricity, ſo that ſometimes one electrization, or two, have been ſufficient. The moſt effectual and ſure method has been that

that of drawing ſparks through flannel, or the cloaths, for about ten minutes, or a quarter of an hour. The patients may be electrified either at the time of the fit, or a ſhort while before the time in which it is expected.

The ſuppreſſion of the ordinary periodical fluxes of women, which is a diſeaſe that often occaſions the moſt diſagreeable and alarming ſymptoms, has been often cured by means of Electricity, even when the diſeaſe has been of long ſtanding, and after the moſt powerful medicines uſed for it have proved ineffectual. Great attention and knowledge is required, in order to diſtinguiſh the arreſt of the periodical fluxes from a ſtate of pregnancy. In the former, the application of Electricity, as we obſerved above, is very beneficial, whereas in the latter, it may be attended with very diſagreeable effects; it is therefore a matter of great importance to aſcertain the real cauſe of the diſeaſe, before the Electricity be applied in thoſe caſes. Pregnant women may be electrified for other diſeaſes, but always uſing very gentle means, and directing the electric fluid through other

parts

parts of the body, diſtant from thoſe ſubſervient to generation. In the real ſuppreſſion of the uſual diſcharges, ſmall ſhocks, *i. e.* of about one-twentieth of an inch, may be ſent through the pelvis; ſparks may be taken through the cloaths from the parts adjacent to the ſeat of the diſeaſe; and alſo the electric fluid may be tranſmitted by applying the metallic or wooden extremities of two directors to the hips, in contact with the cloaths; part of which may be removed in caſe they are too thick. Thoſe various applications of Electricity ſhould be regulated according to the conſtitution of the patient. The number of ſhocks may be about twelve or fourteen. The other applications may be continued for two or three minutes; repeating the operation every day. But either ſtrong ſhocks or a ſtronger application of Electricity, than the patient can conveniently bear, ſhould be carefully avoided; for by thoſe means, ſometimes more than a ſufficient diſcharge is occaſioned, which is not eaſily cured. In caſes of uterine hæmorrhages, I don't know that the application of Electricity was ever beneficial, neither that

it has been often tried.—Perhaps a very gentle electrization, as to keep the patient insulated and connected with the prime Conductor, whilst the electrical machine is in action, may be of some benefit.

In respect to *unnatural discharges* and *fluxes* in general, it may be observed, that some discharges are quite unnatural or adventitious, as the fistula lacrymalis, and some species of the venereal disease; but others are only increased natural discharges, such as the menses, perspiration, &c. Now the power of Electricity, in general, has been found more beneficial for the first, than for the second sort of discharges, which are mostly increased by it.

In the *venereal disease* electrization has been generally forbidden; having mostly increased the pains, and other symptoms, rather than diminished them. Indeed, considering that any sort of stimulus has been found hurtful to persons afflicted with that disorder, it is no wonder that Electricity has produced some bad effects, especially in the manner it was administered

ſtered ſome time ago, *viz.* by giving ſtrong ſhocks. However, it has been lately obſerved, that a very gentle application of Electricity, as drawing the fluid by means of a wooden or metal point, is peculiarly beneficial in various caſes of this kind, even when the diſeaſe has been of long ſtanding. Having remarked above, that tumors, when juſt beginning, are diſperſed, and that unnatural diſcharges are gradually ſuppreſſed by a judicious electrization; it is ſuperfluous to deſcribe particularly thoſe ſtates of the venereal diſeaſe in which Electricity may be applied; it is only neceſſary to remind the operator, to avoid any conſiderable ſtimulus in caſes of this ſort.

The application of Electricity has been found alſo beneficial in other diſeaſes beſides thoſe mentioned above; but as the facts are not ſufficiently numerous, ſo as to afford the deduction of any general rules, I have not thought proper to take any particular notice of them; eſpecially, becauſe the effects of Electricity on the human body, in various circumſtances, have been already

already sufficiently co sidered under general and comprehensive heads.

We may lastly observe, that in many cases, the help of other remedies to be prescribed by the gentlemen of the faculty, is required to assist the action of Electricity, which by itself would perhaps be useless; and on the other hand, electrization may often be applied to assist the action of other remedies, as of sudorifics, strengthening medicines, &c.

" While I was writing some of the " above cases," says Mr. BECKET, " an ob- " servation or two occurred to me, which, " though perhaps of no great consequence, " may not be amiss to mention, as every " particular effect of Electricity seems to " be worthy of notice.

" One circumstance attending some of " the preceding cures, particularly that " of the *paralytic*, related by Mr. JONES, " was a fresh and copious discharge of the " *blisters*, which had been previously ap- " plied

"plied to the patients.—This, I think, "ſeems to be a pretty general conſequence "of electrification; at leaſt, I have myſelf "known many inſtances of it; particu- "larly in one gentleman, whom I elec- "trified for a paralytic complaint, and "who had a bliſter applied to the back "part of his neck. He informed me, "that, in the night after his being elec- "trified the preceding day, he found a "much more copious diſcharge from the "bliſter than at other times; though the "operation was no more than his ſtand- "ing, for about a quarter of an hour, on "the inſulated ſtool, while ſparks were "drawn from the ſide of his face. From "hence it appears not impoſſible, that, in "ſome caſes, bliſters may be attended with "peculiar benefit, during a courſe of elec- "trical treatment; in others, perhaps, it "might be worth while to make uſe of "Electricity, merely to obtain a favourable "diſcharge from the bliſters."

Authentic phyſical Caſes, in which Electricity was adminiſtered.

CASE I.

The particulars of the following caſe were communicated to me by Mr. PARTINGTON.

DANIEL WYSCOYL, aged thirty-ſix, of a ſtrong robuſt conſtitution, was ſent from the Weſtminſter Diſpenſary, in Gerard-ſtreet, to Mr. PARTINGTON, in order to be electrified for a violent inflammation in both his eyes. The account he gave of his diſorder, was the following: — Several dark objects of different ſhapes and ſizes, ſeemed at firſt to obſtruct his ſight. This was ſucceeded by an inflammation in both his eyes, which increaſed with ſuch rapidity, that in a week's time he was brought to the degree of blindneſs that afflicted him till he was electrified. He was immediately recommended to the Weſtminſter Diſpenſary, where every poſſible attention was paid to his misfortune by Mr.

Mr. FORD, the ſurgeon of that place; but the obſtinacy of the diſorder was ſuch, that every endeavour made towards the relief of this poor man proved uſeleſs.—Bliſters and leeches, beſides the other uſual means, were applied without any efficacy whatever.

About two months after the commencement of the inflammation, Mr. FORD recommended him to Mr. PARTINGTON; who, on examining him, found that the eye-lids could not be opened without the help of the fingers, and that when opened, the coats of the eye appeared of an uniform red colour. The ſight of the right eye, which was the moſt affected, was ſo far impaired, that when it was turned towards a window, the eye-lids being forced open, he could perceive only a red glare of light like a ball of fire; but the reſt of the room ſeemed to be equally dark, ſo that he could not diſtinguiſh any object in it. With the left eye he could diſtinguiſh colours, and the ſhapes of objects that were held to him, but in their ſizes he was commonly miſtaken. This diſorder was accompanied with excruciating

pains, ſhifting from one part to the other, but principally inſiſting on his temples, and ſometimes darting to the back part of his head, or to the centre of his eyes.

Mr. PARTINGTON began to electrify him the 21ſt of October, 1776; and three days after the inflammation began viſibly to abate, and in a fortnight's time it was quite ſubſided; but the pupil of the eye was ſo nearly cloſed, that ſcarce any of it could be ſeen. He continued to be electrified every day for five weeks, and the pupil gradually dilated, till he attained a degree of ſight ſufficient to diſtinguiſh objects on the other ſide of the way. The pains had now entirely left him, ſo that he omitted the uſe of Electricity, and did not experience any farther inconvenience after it.

This remarkable cure was effected by throwing the ſtream of electric fluid with a metal, and with a wooden point. The firſt inſtrument uſed, which was contrived by the late Mr. FERGUSON, conſiſted in a pointed braſs wire, faſtened by means of

a cork

a cork at the ſmaller end of a conical glaſs, open at both ends, and paſſing through the axis of this conical or funnel-like glaſs, its point came within about half an inch of the larger aperture of the glaſs. This inſtrument being deſigned to throw the electric fluid upon the eye, was to be fixed ſo that the larger aperture of the glaſs ſurrounding the eye kept its lids open, and the point of the wire was oppoſite to the pupil, and at about half or one inch from it. With this inſtrument it was obſerved that a ſpark often proceeded from the point of the wire, which occaſioned an inſufferable pain; for which reaſon Mr. PARTINGTON, who ſpares no pains to advance this branch of phyſic, thought of improving this inſtrument, by fixing a wooden point upon the pointed wire, by which means the former inconvenience was entirely removed, and the ſtream of electric fluid was rendered more efficacious, and more eaſily manageable.

This, as far as I am informed, was the firſt time that this moſt excellent method of throwing the electric fluid, *viz.* with a wooden point, was uſed.

N. B. The directors described in the preceding pages, the principal of which were contrived by Mr. PARTINGTON, anſwer every required purpoſe, much better than Mr. FERGUSON's inſtrument; the conical glaſs being of no uſe.

CASE II.

The following caſe is related by Mr. LOVETT, in his *Electricity rendered uſeful:*

"Having obſerved the great efficacy of the electrical æther, in ſoon relieving moſt kinds of inflammations, I was inclined to think the ſame ſalutary effects would appear when applied to the St. Anthony's Fire; but when a caſe of that ſort offered, the inflammation was ſo great, that at firſt ſight I almoſt deſpaired of ſucceſs.

"About the middle of the day I made the firſt trial, and before night the ſwelling was much abated, and in a few days quite cured.

"The operation was ſimply drawing ſparks with a finger, or an iron ſtyle, while

the person was electrified on the insulating stool."

CASE III.

The following case is also related by Mr. LOVETT:

"ANN THOMPSON, in Little Fish-street, Worcester, was troubled with a fistula near the inner corner of her eye, which broke out, and healed, no less than seven times. The last time it healed, it continued well for some time; after which it began with a small swelling, and continued growing larger, till it was as big as a filbert; when she was advised to try Electricity. After the swelling was electrified, it soon decreased, till it was entirely dispersed; and has continued well for more than two years, without the least symptom of any return of the disorder. — The operation was simply drawing sparks from the part affected.

CASE IV.

The late Mr. FERGUSON being at Bristol, was seized with a violent sore throat, so that he could not swallow any thing. Being willing to try the power of Electricity, Mr. ADLAM, of that city, performed the operation; which was merely drawing sparks from the throat. The electrization was repeated half an hour after, and was attended with so good and remarkable an effect, that in about one hour's time Mr. FERGUSON could both eat and drink without pain.

CASE V.

The following two cases are related by Mr. JOHN BIRCH, Surgeon.

" A young woman, at the age of twenty-two, desired my advice for a tumor on her thigh, which followed an unhappy accident she met with two years before. Her case was attended with many complicated symptoms, and, among them, a suppres-

sion

ſion of the menſes, which had laſted ſeven months. I thought it right to relieve, if poſſible, this ſymptom, before I proceeded to perform the operation, which was neceſſary for the tumor.

"For three ſucceſſive days I paſſed ſome electric ſhocks through the region of the pelvis; and on the fourth, ſhe was attacked with a violent pain in her ſide, which left her on applying the ſhocks to that part. In about three hours it returned, and I was ſent for. I repeated the ſhocks, and the pain again vaniſhed. I viſited her ſix hours after, when the pain had begun to attack the ſide—I paſſed a ſtronger ſhock, which removed it, and ſhe ſlept well the whole night.—The next day, being the fifth, the menſes appeared, and flowed gently for three days; but ceaſing then, the pain of the ſide returned, and was ſo violent, that I was ſent for in a hurry.—When I came to her, I found her in great agony; but being informed of the cauſe, I begged to make trial of Electricity once more, which ſhe readily conſented to, as ſhe had experienced ſuch inſtantaneous relief before.

—On

—On its application, the pain ceafed.—A very fhort time after, the flux came on, and continued two days.—I attended her for feveral weeks after, upon the former account, and had the pleafure to fee her recover from all her complaints."

CASE VI.

" I was fent for to a lady, who had been afflicted with painful ulcers on both her legs, for more than fifteen months. —They came after a lying-in, and had never healed. The legs were fwelled, but the ulcers had no malignant appearance.—She told me, that fince her laft mifcarriage, which was then more than ten months, fhe had never been regular.— She attributed the pain and fwelling of her legs to that caufe; and, upon enquiry, I found that fhe was fenfible of an endeavour of nature to relieve herfelf at regular periods, and that the pain fhe fuffered at thofe times was alleviated by a bloody difcharge from the ulcers.—I applied the proper dreffings and bandages to the parts, and waited the approach of that period.

In

In about ten days, a pain seized her back, and she began to complain of her legs: I then electrified her; and the next day she was taken out of order, and continued so the whole week.—The ulcers mended from that time, and were healed in three weeks afterwards."

The reader may rest assured, that cases of this sort are so frequent, that perhaps Electricity may be considered as a sure remedy for the arrest of those natural fluxes.

CASE VII.

The following case is extracted from the LXVIIIth volume of the Philosophical Transactions.

A Cure of a muscular Contraction by Electricity. By MR. MILES PARTINGTON, *in a Letter to* WM. HENLY, F. R. S.

Charles-street, Cavendish-square,
June 13, 1777.

"DEAR SIR,

"It is some time since, you informed "me that you had mentioned to Sir JOHN "PRINGLE,

" PRINGLE, Miſs LINGFIELD's cure by " Electricity; that it excited his attention; " and was his opinion, that the com- " munication of it to the Royal Society " would be deemed important and uſeful. " I hope you will not blame my delay in " the compliance with your requeſt. I " have waited for no other purpoſe, than " to obtain the lateſt account of the per- " manency of thoſe good effects, which " ſhe had then but recently experienced, " from our electrical experiments upon " her. Of theſe advantages we have both " had repeated confirmation; and I may " now, I believe, with ſtrict propriety, " from the notes I made for my own ſatis- " faction, ſubmit the following particulars " of them to the inſpection of whomſover " your judgment ſhall direct, or to appro- " priate them to any other purpoſe you " pleaſe. As you were preſent when I firſt " waited on this unhappy young lady, you " will recollect the condition in which we " found her. Her head was drawn down " over her right ſhoulder; the back part " of it was twiſted ſo far round, that her " face turned obliquely towards the oppo-

" ſite

" site side, by which deformity she was " disabled from seeing her feet, or the steps, " as she came down stairs. The *sterno-* " *mostoideus* muscle was in a state of con- " traction and rigidity. She had no ma- " terial pain on this side of her neck; but, " owing to the extreme tension of the " teguments of the left side, she had a pain " continually, and often it was very vio- " lent, particularly in sudden changes of " the weather. Her pulse was weak, " quick, and irregular. She was subject " to a great irritability; had frequently a " little fever, which came on of an even- " ing, and left her before morning: her " spirits were generally exceedingly op- " pressed; and at times she was slightly " paralytic.

" She dated the origin of her disorder " at something more than two years from " that period. She was suddenly seized, " going out of a warm room into the cold " air, with a pain upon the back of her " head, which admitted of small abate- " ment for some months, contracting gra- " dually the muscles to the melancholy

" deformity

" deformity we then beheld; and not-
" withstanding every prudent means had
" been used to subdue it, and she strictly
" adhered to every article prescribed to her
" by the faculty, she was sensible of little
" variation since, and that rather on the
" unfavourable side.

" I urged her to make a trial of Electri-
" city. She was willing while she was in
" London to try the experiment; and
" though the weather was remarkably
" tempestuous, she came to me the first
" tolerable day, and was electrified the first
" time, February 18, 1777.

" I placed her in an insulated chair, and,
" connecting it by a chain to the prime
" Conductor of a large electrical machine,
" I drew strong sparks from the parts af-
" fected, for about four minutes, which
" brought on a very profuse perspiration
" (a circumstance she had been unaccus-
" tomed to) which seemed to relax the
" *mostoideus* muscle to a considerable degree;
" but as the sparks gave her a good deal of
" pain, I desisted from drawing them, and
" only

"only ſubjected her a few minutes longer
"to the admiſſion of the fluid, which paſſed
"off without interruption from the pores
"of her ſkin and adjacent parts. The next
"time ſhe came to me, was the 24th of
"the ſame month. As ſhe had been in the
"afternoon of the firſt day's experiment a
"good deal diſordered, I changed the mode
"of conducting the operation, and ſat her in
"a common dining chair, while I dropped,
"for five minutes, by the means of a large
"diſcharging rod with a glaſs handle, very
"ſtrong ſparks upon the *moſtoideus* muſcle,
"from its double origin at the *ſternum* and
"*clavicula* to its inſertion at the back of the
"head. She bore this better than before,
"and the ſame good effect followed in a
"greater degree, and without any of the
"ſubſequent inconveniences. I ſaw her
"the third time on the 27th. She aſſured
"me ſhe had eſcaped her feveriſh ſymp-
"toms of an evening, and that her ſpi-
"rits were raiſed by the proſpect of getting
"well; that ſince the laſt time I electri-
"fied her, ſhe had more freedom in the
"motion of her head, than ſhe had ever
"experienced ſince the firſt attack of her

"diſorder.

" diſorder. I perſiſted in electrifying her " after the ſame manner, March 3d, 5th, " 6th, 7th, and 9th; from each time ſhe " gained ſome advantage, and her feveriſh " tendency and nervous irritability went off " entirely.

" The weather now ſetting in very un- " favourable, and fearful of loſing the " advantages we had happily reaped from " our early efforts, I requeſted the favour " of you, as the next-door neighbour, to " electrify her every evening while ſhe " was in town, and ſhe might, if any al- " teration took place, ſee me occaſionally. " Fortunately for her, you accepted the " propoſal; and to your judgment and " caution in the conduct of it, for the next " fortnight (three evenings only excepted) " you brought about the happy event; and " have received her teſtimony of gratitude, " for relieving her from a condition, under " which life could not be deſirable, to a " comfortable aſſociation with her family " and friends.

" I am, &c."

" The

"The method I purſued was, to place the lady upon a ſtool with glaſs legs, and to draw ſtrong ſparks, for at leaſt ten minutes, from the muſcles on both ſides of her neck. Beſides this, I generally gave her two ſhocks, from a bottle, containing fifteen ſquare inches of coated ſurface, fully charged, through her neck and one of her arms, croſſing the neck in different directions. This treatment ſhe ſubmitted to with a proper reſolution; and it gave me ſincere pleaſure to find it attended with the deſired ſucceſs.

W. HENLY."

CASE VIII.

The following caſe is extracted from the LXIXth vol. of the Philoſophical Tranſactions.

An Account of a Cure of the St. Vitus's Dance, by Electricity. In a Letter from ANTHONY FOTHERGILL, M. D. F. R. S. *at* Northampton, *to* W. HENLY, F. R. S.

Northampton, Oct. 28, 1778.

SIR,

Agreeable to my promiſe, I now proceed to give you ſome account of a recent

cure performed by Electricity, which will, I think, afford you much pleasure.

Ann Agutter, a girl of ten years of age, of a pale emaciated habit, was admitted an out-patient at the Northampton Hospital on the 6th of June last. From her father's account it appeared (for she was speechless, and with difficulty supported from falling by two assistants) that she had for six weeks laboured under violent convulsive motions, which affected the whole frame, from which she had very short intermissions, except during sleep; that the disease had not only impaired her memory and intellectual faculties, but of late had deprived her of the use of speech.

Volatile and fetid medicines were now recommended, and the warm bath every other night, but with no better success, except that the nights, which had been restless, became somewhat more composed. Blisters and anti-spasmodics were directed, and particularly the flowers of zinc, which were continued till the beginning of July, but without the least abatement of the

symptoms;

ſymptoms; when her father growing impatient of fruitleſs attendance at the hoſpital, I recommended, as a *dernier reſort*, a trial of Electricity, under the management of the Rev. Mr. UNDERWOOD, an ingenious electrician. After this I heard no more of her till the firſt of Auguſt, when her father came to inform me that his daughter was well, and deſired ſhe might have her diſcharge. To which, after expreſſing my doubts of the cure, I conſented; but ſhould not have been perfectly convinced of it, had I not received afterwards a full confirmation of it from Mr. UNDERWOOD, dated September 16; an extract from whoſe letter I will now give you in his own words.

"I have long expected the pleaſure of "ſeeing you, that I might inform you how "I proceeded in the cure of the poor girl. "As the caſe was particular, I have been "very minute, and wiſh you may find "ſomething in it that may be uſeful to "others. If you think it proper, I beg you "will ſtate the caſe medically, and make it "as public as you pleaſe.

" July 5. On the glaſs-footed ſtool for
" thirty minutes: ſparks were drawn from
" the arms, neck, and head, which cauſed
" a conſiderable perſpiration, and a raſh
" appeared in her forehead. She then re-
" ceived ſhocks through her hands, arms,
" breaſts, and back; and from this time
" the ſymptoms abated, her arms begin-
" ning to recover their uſes *.

" July 13. On the glaſs-footed ſtool
" forty-five minutes; received ſtrong ſhocks
" through her legs and feet, which from
" that time began to recover their wonted
" uſes; alſo four ſtrong ſhocks through
" the jaws, ſoon after which her ſpeech
" returned.

" July 23. On the glaſs-footed ſtool
" for the ſpace of one hour: ſparks were
" drawn from her arms, legs, head, and
" breaſt, which for the firſt time ſhe very
" ſenſibly felt; alſo two ſhocks through
" the ſpine. She could now walk alone;
" her countenance became more florid,
" and all her faculties ſeemed wonderfully

* The coated bottle held near a quart.

" ſtrengthened;

" ſtrengthened; and from this time ſhe
" continued mending to a ſtate of perfect
" health.

" Every time ſhe was electrified poſi-
" tively, her pulſe quickened to a great
" degree, and an eruption, much like the
" itch, appeared in all her joints."

Thus far Mr. UNDERWOOD. To complete the hiſtory of this ſingular caſe, I this day (Oct. 28) rode ſeveral miles, on my return from the country, to viſit her; and had the ſatisfaction to find her in good health, and the above account verified in every particular; with this addition, that at the beginning of the diſeaſe, ſhe had but ſlight twitchings, attended with running, ſtaggering, and a variety of involuntary geſticulations, which diſtinguiſh the St. Vitus's Dance; and that theſe ſymptoms were afterwards ſucceeded by convulſions, which rendered it difficult for two aſſiſtants to keep her in bed, and which ſoon deprived her of ſpeech and the uſe of her limbs. The eruptions which appeared on the parts electrified ſoon receded,

without producing any return of the ſymptoms, and therefore could not be called critical, but merely the effect of the electrical ſtimulus. Having given her parents ſome general directions as to her regimen, &c. I took my leave, with a ſtrong injunction to make me acquainted, in caſe ſhe ſhould happen to relapſe. Before I conclude, it may not be improper to obſerve, that ſome time ago, I was fortunate enough to cure a boy who had long had the St. Vitus's Dance (though in a much leſs degree) by Electricity. A violent convulſive diſeaſe, ſomewhat ſimilar to the above, though, if I recollect right, not attended with the *aphonia*, was ſucceſsfully treated in the ſame way by Dr. WATSON, and is recorded in the Philoſophical Tranſactions. May we not then conclude, that theſe facts alone, and more might perhaps be produced, are ſufficient to intitle Electricity to a diſtinguiſhed place in the claſs of anti-ſpaſmodics?

I am, &c.

CASE

CASE IX.

The following is one of thoſe caſes in which the uſe of Electricity was attended with bad ſucceſs: this caſe was related by Dr. HART of Shrewſbury. See the Philoſophical Tranſactions, Vol. XLVIII.

A girl, aged about ſixteen, whoſe right arm was paralytic, being electrified the ſecond time, became intirely paralytic, and remained in that ſtate for about a fortnight; then the ſuperadded paraliſy was removed, by means of ſome medicines; but the arm which was before paralytic, remained ſo. It ſhould be alſo added, that this arm was very much waſted in compariſon to the other. Notwithſtanding the firſt bad accident, it was reſolved to make another trial of Electricity. But after uſing this treatment for three or four days, ſhe became again univerſally paralytic, and even loſt her voice, and could ſwallow with difficulty. This ſecond accident plainly ſhewed

the bad effects of Electricity in that caſe, and the girl, although afterwards relieved of her additional paraliſy, remained in the ſame ſtate ſhe was before the uſe of Electricity.

In this caſe, it is ſuſpected that Electricity was improperly managed; at that time it being uſual to give ſtrong ſhocks, which perhaps were pernicious in the above-mentioned caſe.

CASE X.

The following caſe was performed under the direction of the late Sir WM. WATSON, F. R. S.

A girl belonging to the Foundling-hoſpital, aged about ſeven years, being firſt ſeized with a diſorder occaſioned by the worms, was at laſt, by an univerſal rigidity of the muſcles, reduced to ſuch a ſtate, that her body ſeemed rather dead than alive. After that other medicines had been ineffectually

administered for about one month, she was at last electrified intermittedly for about two months, after which time she was so far recovered, that she could, without pain, exercise every muscle of her body, and perform every action as well as before she had the distemper.

The intelligent reader must have undoubtedly remarked, that in some of the above cases, the electrization administered was rather strong, and different from the general rules given previous to the narration of the cases. But it must be observed, that some of the above cases happened before the principal methods of electrifying, which are now used by the best practitioners, were introduced.—Perhaps, in similar cases, the same salutary event might be produced by a more gentle electrization.

A Letter

A Letter from Mr. Miles Partington *to the Author.*

Cavendish Square, August the 10th, 1781.

SIR,

As the poſſibility of a cure of a fiſtula lacrymalis by Electricity has been publicly queſtioned, I am very glad to comply with your requeſt, in ſtating the ſucceſsful treatment of a diſeaſe of this kind under my own inſpection.

Ann Woodward, between 20 and 30 years of age, was recommended to my care by Mrs. Swift, of King Street, Bloomſbury, in whoſe ſervice ſhe then lived—I was told ſhe had a fiſtula lacrymalis, which had reſiſted every attempt to relieve her. I ſhall deſcribe the ſituation ſhe was in when I firſt ſaw her, and ſhall add her own account anterior to that period. There was a very violent inflammation in the left eye, attended with exceſſive pain, and almoſt continual flux of tears down the cheek, the ſharpneſs of which had conſiderably exco-

riated

riated the ſkin. A little prominence was perceivable on the inner angle of the eye, from which might be generally preſſed a ſmall quantity of matter. The inflammation had been kept up with little abatement for ſix months, during which time a cooling regimen had been particularly enjoined her, and was ſtrictly complied with. Since the inflammation became violent, ſhe had conſtantly awoke in pain, which laſted till twelve o'clock at noon, and was then tolerably eaſy the reſt of the day. She told me, that ſhe had, as long as ſhe remembered, been ſubject to a weak and watery eye, but it had never given her much concern, till ſhe received a cold in it upon her coming to London. In every other reſpect ſhe was remarkably healthy.

My firſt object was to relieve her of the pain. For this purpoſe I conveyed the electric fluid from a wooden point, which generally at the time blunted the acuteneſs of the ſenſation; but which, if by bringing it near to her eye the fluid was concentrated, it always increaſed it to a great degree, though this went off by being

being left to itſelf, or repeating the milder method. I continued in this courſe of treatment for three weeks, when the inflammation was nearly ſubſided, and the pain entirely gone away. Still perceiving the matter to ooze from the inner angle, I ventured to paſs a ſingle electric ſhock down the duct of the noſe, which I effected by placing one of the directors upon the lacrymal ſac, and the other up the noſtril, for the convenience of a more immediate local conveyance. This gave her much pain after the operation; and it remained all the reſt of the day. I found in the morning that ſhe could hardly bear me to preſs upon the ſac, and very little matter came from it. I then paſſed four ſhocks, in the ſmalleſt degree I could convey them, and to be felt, which were not attended with ſo much pain. At bed-time there came on a great throbbing in the part, and in the courſe of the night a large quantity of matter burſt down the noſtril, when ſhe became immediately eaſy. Some matter continued to come away for about four days, and ſhe appeared to be perfectly well. Her eye has been ſince in a ſtronger ſtate than it ever was before.

If

If this ſhould ſtill want additional ſtrength, I am willing to give you farther inſtances of relief in this diſeaſe by Electricity, though they have not been ſo effectually cured.

I ſhall now add a few obſervations, which may perhaps merit your notice. In order to increaſe the power of electrization, I have added a very large coated jar to the prime Conductor of my electrical machine. This jar is placed upon a mahogany ſtand, ſo that the knob of it touches the Conductor. The inſulated chair is alſo in contact with the ſaid Conductor, and the patient is ſeated in it as uſual. With this diſpoſition of the apparatus, the wheel of the machine is firſt turned a few times round; then I apply the metallic rod to the patient, in order to draw the ſparks through the cloaths, or the ſtream of electric fluid by a wooden point, if the diſeaſe ſeem to require ſuch treatment; and I find, that by this means the effects of the electrization are conſiderably increaſed, the pungency of the ſparks is felt much deeper into the electrified part of the body; the heat occaſioned by

by it is alſo greater, and therefore ſeems to be more efficacious for internal complaints. Add to this, that the uſual inconvenience of the diſſipation of the electric fluid into the air is conſiderably prevented.

This diſpoſition of the apparatus does alſo anſwer another purpoſe, which is that of electrifying a patient, without having any aſſiſtant in the room; for after the jar is charged, the turning of the wheel may be diſcontinued, and the patient may continue under the electrization. No ſhock is to be feared from this apparatus; for, ſince the wooden ſtand upon which the jar is fixed is a bad Conductor, the diſcharge can only be made gradually.

I have made another addition to my directors, or rather have contrived a new director, by which an electrified ſtream of water or other fluid is thrown upon any part of the body. This director conſiſts of a ſmall glaſs tube about 3 inches long, and a quarter of an inch in diameter, one extremity of which is drawn to a very fine point, ſuch as the water can hardly paſs

through. This tube I faſten to an inſulating handle, which being made like a pair of pincers, holds it by the middle; I then pour a little water or other fluid into the tube, and by means of a wire connect it with the prime Conductor. When the machine is in motion, the ſtream of water, which the electric fluid forces out of the tube, is very much ſubdivided, and, when directed upon the face, or any naked part of the body, gives an agreeable ſenſation, which not only proves very refreſhing to patients, but in caſes of great irritation of the nerves is often attended with permanent relief. The ſhort experience I have had of theſe directors does not enable me to determine how far they may be uſeful; but in ſeveral inſtances they have afforded conſiderable relief, when other modes of electrization proved uſeleſs.

In the courſe of my practice, I have obſerved a very remarkable effect of Electricity upon the human body, which is, that it removes coſtiveneſs in thoſe perſons that are electrified, eſpecially along the courſe of the alimentary canal. I muſt obſerve,

that

that it does by no means increaſe the evacuations of ordinary good habits of body, but only reinſtates the uſual diſcharge in caſe of coſtiveneſs. This effect ſeems to take place becauſe the electrization gives vigour and energy to the fibres of the debilitated inteſtines, in the ſame manner as it reſtores the loſt motion of more external muſcles.

I am,

Dear Sir,

Yours, &c.

MILES PARTINGTON.

A Letter from DR. JAMES LIND *to the Author.*

Windsor, June the 17th, 1784.

DEAR SIR,

"I here ſend you the account of a remarkable caſe relieved by Electricity whilſt I was at Bombay: if you think it worth publiſhing, I beg you will inſert it in the next publication of your Medical Electricity."

"The wife of an officer of the artillery at Bombay, during the laſt months of her pregnancy, gradually loſt the uſe of her lower limbs, as if it had been a paralyſis, occaſioned by the preſſure of the fœtus upon the nerves which go to thoſe extremities. Her pregnant ſtate did not allow the application of any remedy for the relief of the diſorder. She came to her full time, was ſafely delivered, and though ſhe ſoon recovered in every other reſpect, yet, contrary to every expectation, the paralyſis ſtill remained; nor could it be in the leaſt reliev-

ed by any of the various medicines, which were adminiſtered for about ſeven months, which had elapſed from the time of her delivery, and until I firſt viſited her, which was in June 1780.

" Upon enquiry finding that, of the many remedies likely to afford any relief in ſuch a caſe, Electricity alone had not yet been tried, I immediately recommended the application of it. But the difficulty was to excite an electrical machine in an atmoſphere ſo exceſſively moiſt as that of Bombay was at that time, the rainy ſeaſon being already ſet in; however, the huſband of the patient, being the ſuperintendant of the Military Laboratory of that place, propoſed to try whether an electrical machine could be made to act in a heated room; ſuch as they uſed for the drying of gunpowder. Accordingly a ſmall ſtucco'd room in his houſe was heated by means of burning charcoal, then the doors and windows were thrown open, and an electrical machine being brought in, was found to act very powerfully. Things being thus prepared, my patient began to be electrified, firſt by giving

giving ſparks to her legs and thighs, and afterwards by paſſing about twenty very ſmall ſhocks up one leg and down the other. The effect was really ſurpriſing; for, after the firſt electrization, ſhe was ſo far relieved as to be able to walk up ſome ſteps without any help, which ſhe had not been able to do for many months before. By the ſecond days electrization, which was performed exactly as in the preceding, ſhe was enabled to walk out, and viſit ſeveral of her friends in the neighbourhood. The third day's electrization compleated the cure, and ſhe went about with all the eaſineſs and alacrity in the world. I afterwards received a letter from her huſband, dated May the 29th, 1781, informing me of her continuing in perfect health."

Faithfully yours.

APPENDIX.

N° I.

OF THE VINDICATING ELECTRICITY.

1. AB, *a b*, fig. 6, of Plate IV. reprefents a plate of glafs, coated on both fides with the two metallic coatings CD, *c a*, which are not ftuck to the glafs plate, but are only laid upon it.

From the upper coating CD, three filk threads proceed, which are united at their top H, by which the faid coating may be removed from the plate in an infulated manner, and may be prefented to an electrified electrometer, as reprefented in fig. 7, in order to examine its Electricity. F G is a glafs ftand, which infulates and fupports the plate, &c.

2. Let

2. Let the plate A B, *a b*, be charged in the common manner, by means of an electrical machine, ſo that its ſurface A B may acquire one kind of Electricity, (which may be called K) and the oppoſite ſurface *a b* may acquire the contrary Electricity, (which we ſhall call L). Then, if the coating C D be removed from the plate, and be preſented to an electrified electrometer, as repreſented in fig. 2, it will be found poſſeſſed of the Electricity K, *viz.* of the ſame kind with that which was communicated to the ſurface A B of the glaſs plate; from whence it is deduced, that the ſurface A B has imparted ſome of its Electricity to the coating. Now, this diſpoſition of the charged plate to give part of its Electricity to the coating, is what the learned F. BECCARIA nominates the *Negative vindicating Electricity*.

3. If the coating be again and again alternately laid upon the plate and removed, its Electricity K will be found to decreaſe gradually, till after a number of times (which is greater or leſs, according as the edges of the plate inſulate more or leſs ex-

actly) the coating will not appear at all electrified. This state is called *the limit of the two contrary Electricities*; for if now the above-mentioned operation of coating and uncoating the plate be continued, the coating will be found possessed of the contrary Electricity, *viz.* the Electricity L. This Electricity L of the coating is weak on its first appearance, but it gradually grows stronger and stronger to a certain degree; then insensibly decreases, and continues decreasing until the glass plate has entirely lost every sign of Electricity.

By this change of Electricity in the coating, it is deduced, that the surface A B of the glass plate changes property; and whereas at first it was disposed to part with its Electricity, now (*viz.* beyond *the limit of the two contrary Electricities*) it seems to *vindicate* its own property, that is, to take from the coating some Electricity of the same kind with that of which it was charged: hence this disposition was by F. BECCARIA called the *Positive vindicating Electricity.*

4. This

4. This poſitive vindicating Electricity never changes, though the coating be touched every time it is removed. It appears ſtronger, and continues for a very conſiderable time after the plate has been diſcharged; which is a very ſurpriſing property of glaſs, and probably of all good and ſolid electrics.

5. If, ſoon after the diſcharge of the plate, the coating be alternately taken from the plate, and replaced, but with the following law, *viz.* that when the coating is upon the plate, both coatings be touched at the ſame time, and when the coating is off, this be either touched or not; then the ſurface A B of the plate, on being uncoated every time, takes a quantity of Electricity, which it alternately loſes every time it is coated *.

6. On removing the coating in a dark room, a flaſh of light appears between it and the glaſs, which is ſtill more conſpi-

* This may be proved by touching an inſulated electrometer with the coating, when this is ſtanding upon the plate, and when ſeparated from it.

cuous, if the coating be removed by the fingers being applied immediately to it, *viz.* not in an insulated manner; because, when the coating is not insulated, the glass plate can give to, or receive from it, more of the electric fluid, and that more freely, than otherwise.

7. It is observable, that in the negative vindicating Electricity, the glass loses a greater or less portion of Electricity, in an inverse proportion of the charge given to the plate, *viz.* the part lost is greater when the charge has been the weaker; for in the positive vindicating Electricity, the force of receiving Electricity is stronger, when the charge has been stronger, and contrarywise.

8. If, after every time that the coating C D is removed, the atmospheres E, *e*, that is, the air contiguous to the surface of the glass plate, be examined, they will be found electrified as in the following table, *viz.* the threads of an electrometer, brought within one or two inches, or more, of the surfaces A B, *a b*, will diverge with Elec-

5 tricities

tricities contrary to thoſe expreſſed in the table.

During the time of the negative vindicating Electricity	the air E, if the plate has been charged	moderately	moderately L
		high - -	o
		very high -	moderately K
	the air *e* is electrified L.		

During the time of the poſitive vindicating Electricity	the air E	are electrified L.
	The air *e*	

9. Although we are not acquainted with the cauſe of vindicating Electricity, any farther than to conſider it as a diſpoſition or property of charged glaſs, yet the phenomena of the Electricities of the air, contiguous to the ſurfaces of the plate, ſeem to be a proper conſequence of Dr. FRANKLIN's theory of Electricity, and are accountable by it; for it is a well-known principle of that theory, that when one ſide of a coated electric, fit to receive a charge, acquires a greater quantity of Electricity than the oppoſite ſide can acquire of the contrary Electricity, then both ſides of that electric appear poſſeſſed of the ſame kind of Electricity, namely, of that communicated

municated to the first-mentioned side. Now, when in the negative vindicating Electricity, the surface A B of the glass plate gives part of its Electricity to the coating, then the other side *a b*, being more electrified L, than the side A B is electrified K, it is plain that, according to the said principle, both sides must appear electrified L. But in the positive vindicating Electricity, the side A B of the glass plate receives some Electricity of the kind K from the coating, therefore both sides must affect the air with the Electricity K.

10. There remains only to be explained the reason why, when the plate has received a high charge, the air E, during the time of the negative vindicating Electricity, appears electrified K, whilst the air *e* is electrified L. In order to render this explanation more intelligible, let us suppose the glass plate to have been electrified positively on the side A B; then in the negative vindicating Electricity, the surface A B, on being uncoated, loses a part of its Electricity, which is so much the greater as the charge has been the less (§ 7.); therefore,

therefore, when the charge has been moderate, A B loſes a greater portion of electric fluid, than that with which the air *e* can ſupply the ſurface *a b*; hence the ſurface *a b* will remain more negatively electrified than the ſurface A B is poſitively; conſequently, according to the above-mentioned principle, (§ 9.) both the atmoſpheres E, *e*, muſt appear in a negative ſtate when the charge has been a certain degree higher; then the ſurface A B, on being uncoated, loſes juſt ſo much of the electric fluid as the air *e* can give to *a b*, therefore the air will not appear electrified. But when the charge has been very high, A B loſes a ſmaller portion of electric fluid than the air *e* can give to *a b*; therefore *e*, by having given ſome of its natural electric fluid to *a b*, will appear negative, and E will appear poſitive in a ſmall degree. If the plate be ſuppoſed to have been charged negatively on the ſide A B, the explanation of the phenomena is the ſame, changing only the name of *poſitive* Electricity into *negative*, &c.

11. This property of charged glaſs, called vindicating Electricity, is obſervable

alſo

alſo when two glaſs plates, laid one over the other, and coated on their outward ſurfaces only, are charged jointly like one plate. Suppoſe A B, C D, fig. 8, to repreſent the two plates charged together, *viz.* by having preſented the coating F to the prime Conductor, and having at the ſame time connected the coating G with the ground, in which ſtate, it is eaſy to conceive, that the upper ſurface of the plate A B would be poſitive, its under ſurface would be negative, the upper ſurface of the plate C D, *viz.* the ſurface contiguous to the plate A B, would be poſitive, and its oppoſite ſurface G would be negative. Now if theſe plates, after having been charged, be alternately ſeparated and joined, without ever touching their coatings, it is plain that their ſurfaces, contiguous to one another, whenever the plates are ſeparated, will uncoat each other, conſequently the phenomena of vindicating Electricity will take place, that is, each of the inſide or naked ſurfaces, when the plates are firſt ſeparated, will loſe part of its Electricity. This loſt Electricity gradually decreaſes till it vaniſhes, after which period, each of the

the ſaid ſurfaces will gradually recover part of its loſt Electricity, &c.

12. By the principle noticed above, (§ 9.) when one ſurface of either plate has acquired a quantity of one kind of Electricity more than the oppoſite ſurface has acquired of the other, then both ſurfaces of that plate muſt appear poſſeſſed of that and the ſame kind of Electricity; hence it follows, that when the plates A B, C D, are at firſt ſeparated for a certain number of times, *i. e.* during the negative vindicating Electricity, the plate A B muſt appear poſitive on both ſides, and the plate C D negative on both ſides; but after the *limit of the two contrary Electricities*, when the poſitive vindicating Electricity has taken place, then the plate A B will appear negative on both ſides, and the plate C D poſitive on both ſides.

13. The adheſion of the plates to one another keeps pace with the vindicating Electricity; ſo that it is very ſtrong at firſt, but gradually decreaſes with the negative vindicating Electricity, till it becomes inſenſible;

ſenſible; but after the limit of the two contrary Electricities it appears again, and then it increaſes and decreaſes with the poſitive vindicating Electricity.

14. Every other particular relating to the phenomena of vindicating Electricity, exhibited with one plate, does alſo take place in the experiment with two plates; except the phenomena conſidered above (§ 10.), which the two plates cannot exhibit, on account that they are not capable of receiving a very high charge, as a ſingle plate is; which high charge is abſolutely neceſſary to produce that appearance.

N° II.

OBSERVATIONS UPON THE CONDUCTORS OF LIGHTNING.

SINCE the publication of the First Edition of this Treatiſe, it happened that a houſe belonging to the Board of Ordnance, at Purfleet, was ſtruck by lightning, though furniſhed with a Conductor. This accident excited anew the controverſy relating to the conſtruction of Conductors to ſecure houſes from the effects of lightning, eſpecially relating to their termination; and various experiments were made by very able Electricians, in order to decide the controverted point. Mr. B. WILSON and Mr. ED. NAIRNE, both members of the Royal Society, were the principal actors in this experimental inveſtigation, the former giving conſtantly the preference to ſhort Conductors terminating in a ball, and the latter preferring long Conductors acutely pointed; which has been and is the prevailing opinion with almoſt all the prin-

cipal

cipal Electricians in England, as well as abroad; beginning with the first inventor of those Conductors (the great philosopher Doctor FRANKLIN). Mr. WILSON, the principal and almost the sole opponent of the Franklinian construction of Conductors, exhibited some ingenious electrical experiments upon a large scale; which threw great light upon the property of points in respect to Electricity, and seem at first sight to decide the question in favour of knobbed Conductors, as will appear by the following pages. On the other side, Mr. NAIRNE performed some well-imagined experiments, which seem to establish, beyond any doubt, the prevailing opinion in favour of pointed Conductors; which was afterwards still more confirmed and elucidated by Lord MAHON, now Earl STANHOPE, in his learned work, entitled, *Principles of Electricity*, and published in the year 1779.

Notwithstanding those various disquisitions, and new observations, it seems that what I had previously written, relating to the construction of Conductors, did not require any material alteration; hence I thought proper to reprint, in this Edition, exactly

exactly that which had been advanced relating to Conductors of lightning in my first publication; and have reserved for this dissertation, to make mention of those additional remarks, which, in the present more advanced state of the science, are necessary to be noticed. Mr. WILSON, Mr. NAIRNE, and others, must excuse my giving a very short and summary account of their valuable experiments, since the limits of this work are by far too short to admit a full account of their observations. I shall just mention the principal facts ascertained, so as to make evident the deduction which naturally follows them, and which is necessary to establish the present improved theory of Conductors; omitting those remarks which seem to be not essential, and even dispensing with the particular description of the various apparatuses used for this purpose. The *Board-house*, struck by lightning on the 12th of May 1777, had a pointed iron spike, which projected ten feet above the middlemost and highest part of its roof, and which had a continued metallic communication to the ground. The lightning did no other

damage to this houſe, than to throw down a few ſtones from one of its upper corners, which were next to two iron cramps; which cramps had not a metallic communication with the Conductor. This corner was forty-ſix feet diſtant from the top of the Conductor. In this caſe it is difficult to ſay, whether the lightning ſtruck the Conductor firſt, or the corner of the houſe juſt over the above-mentioned iron cramps, and from thence, being paſſed to the metal which communicated with the Conductor, was conducted to the ground, without cauſing any farther damage to the houſe. In the firſt caſe, the point of the Conductor would, in all probability, have been fuſed, as is generally the caſe; but no mark of fuſion could be perceived on it. The ſecond caſe ſeems not very likely to have happened, ſince the Conductor was far above the corner that was ſtruck, and ſince the lightning is known to ſtrike the moſt elevated objects, and thoſe which have a better communication with the earth, in preference to any other *. In any caſe, the

* Mr. NAIRNE concludes the account of his above-mentioned experiments with the following paſſage:

"I muſt

the only uſeful remark that can be drawn from this accident is, that all the metallic parts, that are in a building, ſhould be connected with the Conductor, otherwiſe it is not unlikely, but that, either by a direct ſtroke, or by a lateral exploſion, the houſe may ſuffer ſome damage from lightning. Mr. WILSON, who had formerly declared his opinion againſt elevated and pointed Conductors, derived from this accident a ſtrong proof apparently in favour of his theory,

" I muſt beg to intrude a little more on your time, " to remark on that part of Mr. WILSON's paper, " where, from his experiments, he ſeems to conclude, " that the lightning at Purfleet firſt ſtruck on the " point of the rod of the Conductor, and then, by a " lateral part of that ſtroke, ſtruck the cramp on the " coping-ſtone. I believe, if he had examined the " ſituation of the ſtone, and the place where the " cramp was ſtruck, he would have found, that, if the " lightning had ſtruck on the point of the Conductor, " that, to have produced that effect on the ſtone, it " muſt, after it had ſtruck on the point, and paſſed " down a quantity, have ſtruck from the metal up into " the air, then down again on the cramp, and then " again to the metal it had left; for the ſmall dent or " hollow made by the lightning was on the upper ſur- " face of the ſtone, and yet the metallic communication " to the earth continued from the point under the ſtone

theory, and soon began to perform several experiments, in which the natural accident was imitated by art *. Mr. WILSON's great apparatus was fixed in the Pantheon, Oxford-street. It consisted principally of the following parts—A cylinder, 16 inches in diameter, and 155 feet long, covered with tin-foil, formed the prime Conductor, which was charged by a good electrical machine of the common sort. This vast Conductor was suspended by various silk strings, at a convenient distance

" which was struck. It appears more probable to me, " from the trifling damage it did, that the charged " cloud had passed over the pointed Conductor, and " had been exhausted of a great part of its Electricity " in passing; and that after it had passed, it was attracted down lower by a ridge of hills that was beyond, and that the cloud being out of the influence " of the point to prevent its striking, the end of the " cloud might strike at an angle in the cramp, and so " to the metallic part of the Conductor, which was " only about 7 inches below. I shall conclude with " observing, that Mr. HENLY and myself had the " pointed rod of the Conductor at Purfleet taken down " to examine the point; but we found no appearance " on it that shewed that it had been struck."

* The account of those experiments is inserted in the 68th vol. of the Phil. Trans.

from

from the floor and walls. To this Conductor there was added a wire 4800 feet long, which was alſo ſupported by ſilk ſtrings, and, on account of its prodigious length, was bent in a great many places, going backwards and forwards in various directions. Sometimes this wire was ſeparated from the great cylinder; but, for the generality of experiments, they were made to communicate together, ſo as to form one extenſive Conductor.—By means of a proper frame and machinery, a wooden model of the above-mentioned houſe, that was ſtruck by lightning, was made to paſs with different required degrees of velocity under and acroſs one end of the great cylinder. This model was furniſhed with a Conductor at top, which was ſometimes terminated in a point, and at other times ended in a ball, but which was made to communicate with the earth by as good a metallic communication as can be deſired by the moſt ſcrupulous experimenter. Whilſt the model of the houſe was kept at a proper diſtance from the great cylinder, and after a known number of turns of the wheel, the model being let go, paſſed under the end of

the cylinder with any required velocity, and at the moment that it paſſed immediately under the charged cylinder, it received the ſtroke from it upon its Conductor, &c. Now the principal experiments which Mr. WILSON made with this apparatus, are briefly expreſſed in the following articles:

1. When the model was furniſhed with a ſharp Conductor, on being made to paſs under the charged cylinder, it drew off a good deal of the electric fluid from it in a ſilent manner, and that abſorption, as it may be ſaid, began long before the model came quite under the cylinder, as was ſhewn by the appearance of light, &c. The charge which afterwards remained in the cylinder was inconſiderable; all which ſhews the tendency that a point has to draw the electric fluid ſilently, and from a diſtance.

2. If, inſtead of a point, the model was furniſhed with a knobbed Conductor of the ſame length with the pointed one, the quantity of electric fluid drawn off in re-

peating the above experiment was not so considerable as before, and it was almost nothing, if the knobbed Conductor was much shorter than the pointed one, as could have been expected.

3. When the model with the sharp Conductor was made to pass under the cylinder fully charged, the pointed Conductor was generally struck with a full and strong explosion; whereas, if the Conductor was terminated in a ball (though of an equal length with the pointed Conductor, and consequently equally distant from the cylinder when the model was just under it) it was not struck, the cylinder remaining charged, &c.

4. "The weight which moved the mo-
"del in the preceding experiment, was
"gradually reduced till it was nearly ba-
"lanced by the friction; and when the mo-
"tion was rendered so slow as seven feet
"seven inches in seven seconds, it was very
"little accelerated; and in this state the
"great cylinder being charged, the model
"was suffered to pass; and, though the

"velocity was leſs than three quarters of a "mile in an hour, the point was ſtruck."

The intelligent reader may remark, that by the above-mentioned obſervations, the already-known properties of points were clearly ſhewn: that the very reaſons before advanced by various philoſophers, for preferring pointed Conductors of lightning to ſuch as are blunted, were confirmed; but, however, that one remarkable obſervation, which could have been hardly believed before, was eſtabliſhed, *viz.* that a point in thoſe circumſtances could receive ſo full a ſtroke, as we have mentioned above. Indeed this is a very good obſervation of Mr. WILSON, and a moſt plauſible argument in favour of his opinion relating to the conſtruction of the Conductors of lightning. Hence he expatiates upon the danger of thoſe houſes, which are furniſhed with elevated and pointed Conductors; and abſolutely recommends knobbed Conductors, which are either even with, or rather a little ſhorter, than the top of a building; ſince, ſays he, the pointed Conductors invite the lightning. It is almoſt ſuperfluous to remark,

that

that it is for that very property, that elevated and pointed Conductors are preferable to knobbed ones, *viz.* becauſe they attract the matter of lightning from a greater diſtance: hence they may defend a greater extent of building; hence, by drawing a conſiderable quantity of electric fluid from the clouds, when at a diſtance, ſo as to leſſen their charge, they may thus actually avoid a full exploſion; the intention of putting a Conductor to a houſe, being to defend the houſe from the bad effects of lightning, and not the Conductor itſelf from attracting the matter of, or being ſtruck by, the lightning.—When the Conductor of a houſe is ſtruck, the only damage it can receive in that caſe, it ſeems, can only ariſe from a lateral exploſion between the Conductor and other pieces of metal, or other very good Conductors, which are contained in the houſe, and are not properly connected with the Conductor. For this reaſon, it is proper to connect with the Conductor, by a metallic communication, all the pieces of metal, and indeed other good Conductors, as a ciſtern of water, &c. that are in a houſe, eſpecially thoſe which are near the outſide,

and

and the top of it. This, however, is almoſt impoſſible to be done perfectly; but then thoſe lateral effects are not of ſo very dangerous a nature, excepting indeed when the building contains ſubſtances of a very combuſtible quality, as gun-powder, &c. in which caſe, the moſt ſcrupulous attention is hardly ſufficient to prevent any bad accident. Notwithſtanding the obviouſneſs of the above-mentioned remarks, Mr. WILSON's experiments determined ſeveral perſons in favour of the knobbed Conductors: hence Mr. NAIRNE undertook to oppoſe Mr. WILSON's theory with a clear and convincing ſet of experiments. The prime Conductor uſed by Mr. NAIRNE was one foot in diameter, and ſix feet long, conſequently by far ſmaller than that uſed by Mr. WILSON. The other apparatus was different, and the electrical machine was much more powerful than that uſed by Mr. WILSON *. But with this apparatus he amply ſhows the properties of points and knobs, with reſpect to Electricity; and, different from Mr. WILSON, ſhows, that in

* See Mr. NAIRNE's account of thoſe Experiments, &c. in the 68th vol. of the Phil. Tranſ.

many

many experiments, and under various circumſtances, a knob is ſtruck in preference to a point. This diverſity of appearances, and reſults of experiments, in caſes ſeemingly alike, will at firſt ſight be thought a contradiction; but, when duly conſidered, the different phenomena may be all reconciled to a few very ſimple and natural propoſitions. A point draws the electric fluid of an electrified body, from a much greater diſtance than a blunt-terminated body; but the quantity muſt be limited, and ſubject to be altered by many cauſes; ſuch are, the degree of condenſation of the electric fluid upon the electrified body; the time given to the point; the acuteneſs of the ſaid point; its free or encumbered ſituation; its perfect or imperfect communication with the earth, &c. Thus, if the pointed body be not made to communicate with the earth, but the communication be interrupted by a ſhort interval, then, on preſenting a body ſufficiently charged with electric fluid, to the ſaid point, a full ſpark will go from the former to the latter, becauſe the point, on account of the interruption of communication, cannot diſ-

charge

charge to the earth, or other fit body, the electric fluid by little and little, consequently cannot receive it silently from the electrified body to which it is exposed, but can attract only that quantity which can leap between the interruption, and which passes in the form of a spark. Thus also, if the point is suddenly brought within a sufficient distance of a strongly-electrified body, it will receive a spark, because a sufficient time was not allowed it to draw off the electric fluid silently, as would happen if the point was gradually brought near. After the same manner, the ingenious reader may imagine a great multiplicity of cases, in which a point may be struck or not struck by an electrified body; hence is derived the apparent contradiction between the experiments of Mr. HENLY, Mr. WILSON, Mr. NAIRNE, and various others: but it always remains true, that a pointed or sharp-edged body draws the electric fluid from a greater distance than those bodies which are blunt or more obtuse, all the other circumstances being the same in both cases.

Lord STANHOPE, in his above-mentioned work, ſhews a property of electric atmoſpheres, which he calls the *returning ſtroke*, and which he is of opinion that can occaſion great damage in ſome caſes. This is that quantity of electric fluid, which, by the vicinity of a cloud highly electrified, is driven away from certain bodies, and which ſuddenly returns to thoſe bodies when the cloud happens to diſcharge its Electricity by a ſtroke of lightning to any other body; for then the atmoſphere which kept off the electric fluid of the bodies that were within its action, ceaſes at once. Our noble author ſhews experimentally, that ſuch a returning ſtroke may occaſion great damage, even at a good diſtance from the place where the ſtroke of lightning happens, and that its effects may be very conſiderable; all which confirms the already-made obſervation, *viz.* that all the beſt and largeſt conducting bodies that are in a houſe, ſhould be connected with the Conductor of lightning. Without detaining my reader with further diſquiſitions, I ſhall only take notice of the moſt notable particulars that ſhould be kept in view,

and

and ſhould be conſidered as the leading principles, in erecting Conductors for the lightning; and ſhall then conclude with the *requiſites neceſſary* for the proper conſtruction of Conductors, which requiſites I ſhall tranſcribe exactly from Lord STANHOPE's work.

A pointed body attracts the matter of lightning more or leſs eaſily, according as it is more or leſs acute; according as it is leſs or more encumbered by ſurrounding bodies; or as it is more or leſs elevated, and as its communication with the earth, by means of conducting bodies, is more or leſs perfect. The clouds are bad Conductors, and in general the electric fluid is not highly concentrated on them in proportion to their extent; they are often ſeparated from each other; they may come towards a Conductor or a houſe in every direction; and move with various velocities at different times. The pointed Conductor that is erected in order to tranſmit the lightning with ſafety to the ground, can only defend a limited extent of building, the quantity of which varies according to many circumſtances.

ſtances. In caſes of powder-magazines, and ſuch-like very combuſtible ſubſtances, great damage may be occaſioned by a lateral exploſion or returning ſtroke, if the Conductor happened to be ſtruck; which may be only avoided by making a proper communication between all the ſubſtances of a good conducting nature that are in the building. It has been obſerved, that ſometimes a ſtroke of lightning is branched, and ſtrikes ſeveral objects at the ſame time.

In conſequence of all thoſe obſervations, and various others mentioned in the courſe of this book, it ſeems proper to have in view the following inſtructions, in erecting Conductors for the lightning.

1. "That the *rods* be made of ſuch ſubſtances as are, in their nature, the beſt *Conductors* of Electricity.

2. "That the rods be *uninterrupted*, and perfectly *continuous*."

3. "That they be of a *ſufficient thickneſs*."

4. "That they be perfectly *connected* with the *common-ſtock*."

5. "That

5. "That the upper extremity of the rods be as *acutely pointed* as poſſible."

6. "That it be *very finely tapered.*"

7. "That it be *prominent.*"

8. "That each rod be carried, in the *ſhorteſt convenient direction*, from the point at its upper end, to the *common-ſtock.*"

9. "That there be neither *large* nor *prominent* bodies of metal upon the top of the building propoſed to be ſecured, but ſuch as are *connected with the Conductor* by ſome proper metallic communication."

10. "That there be a ſufficient *number* of high and pointed rods:" And,

11. "That every part of the rods be very *ſubſtantially* erected."

N° III.

EXTRACT OF A LETTER FROM MR. ARDEN, LECTURER IN NATURAL PHILOSOPHY, DATED SEPTEMBER 25, 1772.

"ABOUT fourteen or fifteen years ago, in the preſence of WM. CONSTABLE, Eſq; at his ſeat at Burton Conſtable, in Holderneſs, I made the following experiments:

" I placed a large coated jar, that would hold three or four gallons, directly under the prime Conductor of a very good electrical machine. The prime Conductor was at leaſt eight or ten inches above the top of the jar, and the communication was made by a braſs wire, bent at one end over the prime Conductor, and the other end paſſed through a ſmall glaſs tube (contrived by Mr. CONSTABLE to prevent the electric matter from eaſily flying off) was ſuſpended in the middle of the jar, and had a ſmall piece of braſs chain faſtened to it, that reſted on the bottom of the jar.

" I then began to turn the wheel, and, after turning about 100 or 150 times, as low in the jar as I could ſee for the coating, I perceived a ball of fire, much reſembling a red-hot iron bullet, and full three quarters of an inch in diameter, turning round upon its axis, and aſcending up the glaſs tube that contained the braſs wire, which was the Conductor to the inſide of the jar.

" I immediately aſked Mr. CONSTABLE, if he ſaw the ball of fire? he ſaid, Certainly. I ſaid, I will turn on. He anſwered, By all means. I kept turning the wheel, and the ball of fire continued turning upon its axis, and aſcending up the glaſs tube till it got quite upon the top of the prime Conductor. There it turned upon its axis ſome little time, and then gradually deſcended, turning upon its axis as it had done in its aſcent, and ſo continued till it was ſo much below the top of the coating that we could no longer ſee it. But ſoon after this, a very great flaſh was ſeen; a large exploſion was heard, and ſtrong ſmell of ſulphur was perceived all over the room;

a round

a round aperture was cut through the ſide of the jar, as fine as if it had been cut with a diamond, rather more than three quarters of an inch in diameter, and between two and three inches below the top of the coating, and the coating was torn off all round the aperture, about three or four inches in diameter. The jar was a pretty ſtrong one, of crown glaſs.

" I then took another jar, ſo like the firſt, that when both were whole I could not eaſily perceive any difference between them. I then attempted to charge this jar, in the ſame manner as the other, and we both obſerved it very accurately. No ball of fire was ſeen, but preſently the jar diſcharged itſelf with a great flaſh and exploſion, and at about the ſame part as of the firſt jar; but inſtead of the aperture which was made in the firſt jar, there was a circle about three quarters of an inch diameter, as white as chalk, and the coating torn off round about it as before. Upon touching the white part, it dropped out, and appeared to be glaſs in a fine powder.

"We broke ſeveral other different-ſized jars that day, (which made Mr. CONSTABLE ſay we were in great luck) but without any thing elſe remarkable.

"The firſt experiment was made ſoon in the afternoon of a clear day, and the machine ſtood directly between us and a window, which was not above a yard from it. I don't hear that this ball of fire has been produced by art by any one elſe, to this day, although it is often produced by nature.

"I had the pleaſure of ſeeing Mr. CONSTABLE this day, and of reading the account of theſe experiments to him, and, to the beſt of his memory, he thought the whole was ſtrictly true.

"Mr. CONSTABLE thinks it would not be difficult to repeat the experiment, and to produce the ball of fire at any time, provided the jar is large, and not coated too near the top, and that the wire communicating from the prime Conductor to the inſide of the jar is made to paſs through a ſmall glaſs

glaſs tube, (which is certainly of great advantage in making experiments of this kind) and that the machine acts very ſtrong. If not, it will be in vain to attempt it."

AFTER this letter. Dr. PRIESTLEY, out of whoſe works it has been tranſcribed, ſubjoins the following remarks *:—" The fact mentioned in the preceding letter is of a very remarkable nature, and, being perfectly well aſcertained, it is of importance that it be generally known, and kept in view. For though no perſon, that has hitherto been made acquainted with it, has been able to repeat the experiment, others may be more fortunate. Dr. FRANKLIN, and, if I miſtake not, Mr. CANTON alſo, and myſelf, were preſent when Mr. HENLY endeavoured to produce this appearance; but, though every expedient that any of us could ſuggeſt was made uſe of, we had no ſucceſs, and I have ſeveral times attempted it in vain ſince. I ſhall not, however, deſiſt from my attempts."

* Experiments on Air, &c. vol. v.

"Mr. ARDEN's own evidence is abundantly ſufficient to authenticate the fact, and I have ſince had from Mr. CONSTABLE himſelf the ſame account of it. Could we repeat this experiment, there would not, I think, be any natural phenomenon in which the electric fluid is concerned, that we could not imitate at pleaſure. This circumſtance alone makes it a very intereſting object of inveſtigation."

N° IV.

OBSERVATIONS CONCERNING SOME PROPERTIES OF THE ELECTRIC FLUID.

AMONGST the various experiments performed by Mr. WILSON in the Pantheon, as mentioned in the preceding pages, he made ſome with a long wire, which was ſuſpended by ſilk lines, and went in various directions through that great building. This wire was 4800 feet long, and $\frac{1}{21}$ of an inch in diameter. It conſiſted of many pieces, which were connected by twiſting the ſeveral ends together. —Mr. WILSON electrified this extended wire by means of an electrical machine ſituated next to one of its extremities; and when the wire was fully charged, which happened after a few turns of the wheel, a perſon diſcharged it, by preſenting his hand to it, which was attended with a ſhort ſpark, but with a very diſagreeable ſtrong ſhock. Then Mr. WILSON took an equal length of wire, of the ſame diameter with

the above-mentioned extended one, and, putting it all coiled together upon a glaſs ſtand, charged it with electric fluid, by means of the ſame machine, and when this wire was fully charged, which took place after about half a turn of the wheel, a ſpark was taken from it, but which occaſioned a ſenſation by no means comparable with that given by the extended wire, ſince this, though longer than the ſpark of the extended wire, was hardly to be felt, whereas that was remarkably ſtrong.

The explanation of thoſe effects might eaſily occur to a perſon little verſed in Electricity. The extended wire acquired a much greater quantity of Electricity than that which was coiled up, for the ſame reaſon for which an extended piece of tin-foil, twenty ſquare feet in ſurface, and which weighs one pound, can acquire incomparably more Electricity than a ſolid ball of tin, which weighs one pound alſo; namely, becauſe the extended wire expoſes a far greater ſurface to the free air, than the wire that is coiled up; and the ſpark given by the coiled wire is longer than that given by

by the other, in ſo much as the electric fluid, whatever its quantity may be, can be much more condenſed on the coiled, than on the extended wire; it being well known, that the length of the ſpark given by electrified Conductors is proportional to the condenſation, and not to the quantity of electric fluid.

To obſerve, that the extended wire required many turns of the wheel before it became charged, whereas the coiled wire required leſs than one turn; the obſervations made and mentioned by various writers on Electricity, relating to the capacity of Conductors under various circumſtances; Dr. FRANKLIN's experiment of the *can* and *chain*, and innumerable other experiments of the like nature, might have convinced Mr. WILSON of the truth of the above-mentioned natural and clear explanation; but, upon thoſe phenomena Mr. WILSON eſtabliſhes a principle which does not ſeem ſatisfactory. He imagined, that in ſo much the extended wire gave a much ſtronger ſhock than that which was coiled up, as the electric fluid percurring the

whole

whole length of the extended wire acquired a great degree of velocity; hence the impetus with which it ſtruck the hand or other body preſented to the charged wire, occaſioned that diſagreeable ſenſation, which ſenſation was not accompanied with the ſpark given by the coiled wire, becauſe the electric fluid could not acquire any velocity, as it did not go through a great extent of conducting ſubſtance.

This theory ſeems to be not true, for the following reaſons. Firſt, It is well known that metal, and in general any ſort of conducting ſubſtance, does in ſome meaſure reſiſt the free paſſage of the electric fluid through its ſubſtance; hence the electric fluid, in going through a long Conductor, muſt be retarded rather than accelerated. Secondly, The electric fluid being elaſtic, whenever a way is opened for it to eſcape out of a Conductor, upon which it has been confined, it muſt exert its greateſt force at firſt; that is, the quantity of it, which comes out at firſt, has the greateſt velocity, becauſe it is impelled by the greateſt expanſive force; but, according as more and

more

more of the electric fluid comes out of the Conductor, that impelling force or elasticity decreases; hence the last particles of electric fluid come out of the Conductor with much less velocity; thus in a condensing fountain, out of which the stream of water issues, on account of the elasticity of the air condensed in the cavity of the instrument, the stream at first comes out with greater violence, and mounts higher up, but afterwards loses its velocity by degrees, because the condensed air becomes gradually less and less condensed, and consequently exerts a force continually smaller and smaller against the water. Lastly, It may be observed in general, as it has been proved by many experiments, that if two unequal Conductors, one of which A is more extended than the other B, discharge equal quantities of electric fluid under the form of sparks from like terminations, the spark given by A is less strong than the spark given by B, and that for the above-mentioned reasons.

Notwithstanding the obviousness of those remarks, Mr. Wilson, since he first made the

the experiments at the Pantheon, ſeems to have become continually more and more attached to his opinion, ſo that ſome time ago, he publiſhed a ſmall tract, entitled, *A ſhort View of Electricity*, in which he endeavours to eſtabliſh his theory of the acceleration of the electric fluid, &c. upon mathematical principles. This ſtep determined me to take notice of it in this Appendix, in order to prevent any wrong notions in the heads of novices; for perſons who are not converſant with mathematics, will take any propoſition for true, when they are told that it is mathematically ſo. Mr. WILSON's theorem conceals a fallacy, and ſhews that a perſon very well ſkilled in a ſcience, as Mr. WILSON is in Electricity, can eaſily fall into a miſtake, when he is too much attached to a favourite opinion.—Mr. WILSON's words are the following:

"*Upon Acceleration.*

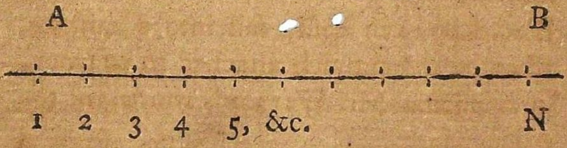
"The experiments at the *Pantheon*, "which were intended to ſhew the acce- "leration of the fluid, having been object- "ed to by many, who have not ſufficiently "attended

" attended to the known properties of the " elastic fluid, it has been thought proper " here to establish this very material point " upon mathematical principles, with a view " to put an end to all farther disputes on the " subject.

" But before this is done, it may be " necessary to mention a material fact that " was omitted in the account of those ex- " periments; which is this,

" The shock received at the *middle* of " the long wire, was *considerably* less than " that which was received at either end.

" THEOREM.



" Let A B represent a cylinder of a given " diameter, and suppose this cylinder " charged with the electric fluid. I say, if " all the particles of this fluid are moved " at the same instant towards A, the effect " produced by the shock of this fluid at

" A will

"A will be nearly proportional to the "ſquare of AB; for the total effect at "A is equal to the ſum of the effect of each "particle contained in the cylinder AB: "and the effect of each particle being pro- "portional to its velocity, the total effect "at A will be proportional to the ſum of "all the velocities. But ſince the fluid is "ſuppoſed nearly perfectly elaſtic, all the "particles will arrive at A nearly at the "ſame inſtant; then the velocity of each "particle will be proportional to the diſ- "tance from the place it ſets out, and the "total effect at A will be proportional to "the ſum of all thoſe diſtances.

"But all thoſe diſtances are expreſſed "by the following numbers, 1, 2, 3, 4, 5, "&c. - - - - - - N (N expreſſing the "length AB) in an arithmetical progreſ- "ſion. Then the ſum of all the diſtances "will be expreſſed by the ſum of the "arithmetical progreſſion 1, 2, 3. 4, 5, "&c. - - - - - - N, and the effect at A "will be proportional to this ſum, that is "to ſay, to N^2 or AB^2. Q. E. D."

Mr.

Mr. WILSON's abſtract propoſition is certainly evident, *viz.* "That if all the particles of the electric fluid are moved at the ſame inſtant towards A, (by which, I ſuppoſe, he means if they arrive at A in the ſame inſtant of time) the effect produced by the ſhock of this fluid at A will be nearly proportional to the ſquare of A B." But this propoſition cannot be poſſibly applied to the matter of fact, or actual experiment, ſince the condition upon which the propoſition depends cannot be verified; *viz.* we do not know whether or no the particles of the electric fluid that are in the long wire, do all arrive at one end of it preciſely at the ſame time. Beſides, we may ſafely ſay, that from the conſiderations mentioned in the preceding pages, and from the analogy of other natural phenomena, it appears that they do not, and cannot arrive to the extremity of the wire preciſely at the ſame time. Between the particles of electric fluid which arrive firſt at one extremity of the wire, and thoſe which arrive laſt at the ſame extremity, there is an interval, a difference of time. Mr. WILSON ſays, "all the particles will arrive at

A, *nearly*

A, *nearly* at the ſame inſtant." Now, even that *nearly* implies a length of time, which, however imperceptible it may be to our ſenſes, is yet ſufficient for the natural operation. For inſtance, ſuppoſe that the extended and electrified wire is a mile long, and alſo ſuppoſe that a quantity of electric fluid employs one hundredth part of a ſecond of time to go through that length of wire, and that without acceleration, or even with a little retardation, which is by no means an exaggerated ſuppoſition. Now, if a way be opened to the electric fluid in the wire, *viz.* the hand, &c. be preſented to one extremity of it, the neareſt particles of the electric fluid will come out firſt, and the remoteſt laſt; yet that difference, agreeably to the ſuppoſition, does not exceed one hundredth part of a ſecond, which is abſolutely unperceivable by our ſenſes; ſo that the appearance is exactly the ſame as if all the particles of the electric fluid came out of the extremity of the wire preciſely at the ſame inſtant of time. I think, therefore, that what Mr. WILSON imagines to have eſtabliſhed upon mathematical principles, is far from being mathematically demonſtrable. Without dwelling

any longer upon Mr. WILSON'S proposition, and the corollaries which he deduces from it, I ſhall only take notice of a remarkable experiment he made at the Pantheon, with the already-mentioned apparatus; which, however, he attributes to the increaſed velocity, which the electric fluid acquired in percurring the ſubſtance of a very long Conductor.

Mr. WILSON fired gunpowder by means of the ſtream of electric fluid, but without ſpark or ſhock. The method is as follows, in his own words: "Upon a ſtaff of baked "wood a ſtem of braſs was fixed, which "terminated in an iron point at the top. "This point was put into the end of a "ſmall tube of Indian paper, made ſome-"what in the form of a cartridge, about "two-tenths of an inch in diameter. "When this cartridge was filled with "common gunpowder (unbruiſed), the "wire of communication with the well "was then faſtened to the bottom of the "braſs ſtem. Being ſo circumſtanced, and "whilſt the charge in the great cylinder "and wire was continually kept up by

" the motion of the wheel, the top of the " cartridge was brought ſo near to the " drums as frequently to touch the metal. " In this ſituation, a ſmall, faint, lumi- " nous ſtream was obſerved between the " top of the cartridge and the metal " drum.

" Sometimes this ſtream would ſet fire " to the gunpowder at the inſtant of the " application; at others, it would require " half a minute, or more, before it took " effect. But this difference in time might " probably ariſe from ſome difference in the " circumſtances; for any the leaſt moi- " ſture, &c."

It ſeems that in this experiment the gunpowder was fired by the heat occaſioned by the denſe ſtream iſſuing out of the vaſt Conductor, which diſcharged a prodigious quantity of electric fluid in that concentrated manner. This experiment was afterwards imitated by Mr. NAIRNE, with the Leyden phial. When a large electric jar was charged, Mr. NAIRNE preſented the cartridge of gunpowder, ſimilar to that uſed

ufed by Mr. WILSON, to the knob of the jar, and the powder was fired without any explofion of the jar. In this experiment, the wire upon which the cartridge was fixed, did not communicate with the outfide of the jar by a good conducting communication, but both the outfide of the jar, and the faid wire, did communicate with the ground; fo that it may be faid, that the circuit between the two fides of the jar was imperfect; hence the difcharge was not made by a full explofion.

N° V.

EXTRACTS FROM MR. VOLTA'S PAPER,

Inferted in the 72d vol. of the Phil. Tranf.

Concerning the Capacity of Conductors, a new Method of difcovering very fmall Degrees of Electricity, and the Electricity of the Atmofphere.

MR. VOLTA's paper on the method of difcovering the fmalleft degrees of Electricity, either natural or artificial, containing feveral particulars not only new, but alfo very interefting to electricians, it was deemed neceffary to infert in this book at leaft a fummary account of them; and had the limits of the work permitted it, I fhould have tranfcribed the whole paper; however the extracts are fuch as, I imagine, will convey a diftinct idea of the difcoveries of that excellent electrician, and will leave out not more than what the ingenuity of the reader may eafily fupply. I have generally ufed the

words of Mr. VOLTA himſelf; but I have changed in great meaſure the order of the paragraphs, for the ſake of rendering the ſubject more intelligible in a contracted ſtate.

Conducting bodies, of the ſame ſhape, will contain a greater or leſs quantity of Electricity, according as their ſurfaces are leſs or more influenced by *homologous atmoſpheres*; and the capacity of a Conductor, which has neither its form nor ſurface altered, is increaſed when, inſtead of remaining quite inſulated, the Conductor is preſented to another Conductor not inſulated, and this increaſe is more conſpicuous, according as the ſurfaces of thoſe Conductors are larger and come nearer to each other.—When an inſulated Conductor is oppoſed or preſented to another Conductor whatever, Mr. VOLTA calls it a *conjugate Conductor*.

In order to ſhew by experiment the above-mentioned property or increaſe of capacity in a Conductor, take the metal plate of an electrophorus, and holding it by its inſulating handle in the air, electrify it ſo high, as that the index of an electrometer an-

nexed to it might be elevated to 60°; then lowering this metal plate by degrees towards a table or other conducting plain ſurface, you will obſerve that the index of the electrometer will fall gradually from 60° to 50°, 40°, 30°, &c. Notwithſtanding this appearance, the quantity of Electricity in the plate remains the ſame, except the ſaid plate be brought ſo near the table as to occaſion a tranſmiſſion of the Electricity from the former to the latter; at leaſt the quantity of Electricity will remain as much the ſame as the dampneſs of the air, &c. will permit. The decreaſe, therefore, of intenſity is owing to the increaſed capacity of the plate, which is now *conjugate*, *viz.* oppoſed to another conducting ſurface. In proof of which, remove gradually the metal plate from the table, and it will be found that the electrometer riſes again to its former ſtation, namely to 60°, excepting the loſs of that quantity of Electricity, which during the experiment muſt have been imparted to the air.

The reaſon of this phenomenon is eaſily derived from the action of electric atmoſpheres.

ſpheres. The atmoſphere of the metal plate, which, for the preſent, we ſhall ſuppoſe to be electrified poſitively, acts upon the table or other Conductor to which it is preſented; ſo that the electric fluid of the table, agreeably to the known laws, retiring to the remoter part of it, becomes more rare in thoſe parts which are expoſed to the metal plate, and this rarefaction becomes greater, the nearer the electrified metal plate is brought to the table. If the metal plate be electrified negatively, then the contrary effects muſt take place. In ſhort, the parts immerſed into the ſphere of action of the electrified metal plate, contract a contrary Electricity, which *accidental* Electricity, making in ſome manner a compenſation for the *real* Electricity of the metal plate, diminiſhes its intenſity, as is ſhewn by the depreſſion of the electrometer.

The two following experiments will throw more light upon the reciprocal action of the electric atmoſpheres. Firſt, ſuppoſe two flat Conductors, electrified both poſitively or both negatively, to be preſented towards, and to be gradually brought near,

each other; it will appear by two annexed electrometers, that the nearer those two Conductors come to each other, the more their intensities will increase; which shews, that either of the two *conjugate* Conductors has a much less capacity now, than when it was singly insulated, and out of the influence of the other. This experiment explains the reason why an electrified Conductor will shew a greater degree of intensity when it comes to be contracted into a smaller bulk; and also why a long extended Conductor will shew a less degree of intensity than a more compact one, supposing that the quantity of surface and of Electricity is the same in both; because the homologous atmospheres of their parts interfere less with each other in the former than in the latter case.

Secondly, let the preceding experiment be repeated, with this variation only, *viz.* that one of the flat Conductors be electrified positively, and the other negatively: the effects then will be just the reverse of the preceding; *viz.* the intensities of their Electricities will be diminished, because their

their capacities are increaſed, the nearer the Conductors come to each other.

Let us now apply the explanation of this laſt experiment to that of bringing an electrified metal plate towards an uninſulated conducting plane; for as this plane acquires a contrary Electricity by the vicinity of the electrified plate, it follows that the intenſity of the Electricity of the metal plate muſt be diminiſhed, and in the ſame proportion its capacity is increaſed; conſequently the metal plate in that caſe may receive a greater quantity of Electricity.

This property may be rendered ſtill more evident, by inſulating the conducting plane whilſt the electrified plate is very near it, and afterwards ſeparating them; for then both the metal plate and the conducting plane (which may be called the *inferior* plane) will be found electrified, but poſſeſſed of contrary Electricities, as may be aſcertained by electrometers.

If the inferior plane be inſulated firſt, and then the electrified plate be brought over it, then

then the latter will cauſe an endeavour in the former to acquire a contrary Electricity, which however the inſulation prevents from taking place; hence the intenſity of the Electricity of the plate is not diminiſhed, at leaſt the electrometer will ſhew a very little and almoſt imperceptible depreſſion, which is owing to the imperfection of the inſulation of the inferior plane, and to the ſmall rarefaction and condenſation of the electric fluid, which may take place in different parts of the ſaid inferior plane. But if in this ſituation the inferior plane be touched, ſo as to cut off the inſulation for a moment, then it will immediately acquire the contrary Electricity, and the intenſity in the metal plate will be diminiſhed.

If the inferior plane, inſtead of being inſulated, were itſelf a non-conducting ſubſtance, then the ſame phenomena would happen, *viz.* the intenſity of the electrified metal plate laid upon it would not be diminiſhed. This, however, is not always the caſe; for if the ſaid inferior non-conducting plane be very thin, and be laid upon a Conductor, then the intenſity of the electrified

metal

metal plate will be diminiſhed, and its capacity will be increaſed by being laid upon the thin inſulating ſtratum; becauſe in that caſe the conducting ſubſtance, which ſtands under the non-conducting ſtratum, acquiring an Electricity contrary to that of the metal plate, will diminiſh its intenſity, &c. and the inſulating ſtratum will only diminiſh the mutual action of the two atmoſpheres, more or leſs, according as it keeps them more or leſs aſunder.

The intenſity or electric action of the metal plate, which diminiſhes gradually as it is brought nearer and nearer to a conducting plane not inſulated, becomes almoſt nothing when the plate is nearly in contact with the plane, the compenſation or accidental balance being then almoſt perfect; hence if the inferior plane only oppoſes a ſmall reſiſtance to the paſſage of the Electricity (whether ſuch reſiſtance be occaſioned by a thin electric ſtratum, or by the plane's imperfect conducting nature, as is the caſe with dry wood, marble, &c.) that reſiſtance, and the interval, however ſmall, that is between the two planes, cannot be over-

come

come by the weak intenſity of the Electricity of the metal plate, which on that account will not dart any ſpark to the inferior plane (except its Electricity were very powerful, or its edges not well rounded) and will rather retain its Electricity; ſo that, being removed from the inferior plane, its electrometer will nearly recover its former height. Beſides, the electrified plate may even come to touch the imperfectly conducting plane, and may remain in that ſituation for ſome time: in which caſe the intenſity being reduced almoſt to nothing, the Electricity will paſs to the inferior plane exceedingly ſlowly.

But the caſe will not be the ſame, if, in performing the experiment, the electrified metal plate be made to touch the inferior plane *edgewiſe*; for then its intenſity being greater than when laid flat, as it appears by the electrometer, the Electricity eaſily overcomes the ſmall reſiſtance, and paſſes to the inferior plane, even acroſs a thin electric ſtratum; becauſe the Electricity of one plane is balanced by that of the other, only in proportion to the quantity of ſurface

face which they oppofe to each other within a given diftance; whereby, when the metal plate touches the other plane in flat and ample contact, its Electricity is not diffipated.

This explanation, properly applied, renders evident the action of *points* in general. Juftly fpeaking, a pointed Conductor, not infulated, when prefented to an electrified body, has not in itfelf any particular virtue of attracting Electricity. It acts only like a Conductor not infulated, which does not oppofe any refiftance to the paffage of the electric fluid. If the fame Conductor, inftead of being pointed, were to prefent a globular or flat furface to the electrified body, neither in that cafe it would oppofe a greater refiftance to the paffage of the Electricity. But the reafon why the Electricity will not pafs nearly fo eafily from the electrified body to the globular or flat conductor, as to the pointed one, is becaufe in the former cafe the intenfity of the Electricity in the electrified body is weakened by the oppofed flat furface, which, acquiring the contrary Electricity, compenfates the diminifhed

minished intensity incomparably more than a point is able to do. It appears, therefore, that it is not the particular property of a point or of a flat surface, but the different state of the electrified body, that makes it part with its Electricity easier, and from a greater distance, when a pointed conducting substance, than when a flat globular one, is presented to it.

What looks like a paradox in the case of an electrified plate standing upon an imperfectly conducting plane, is, that the metal plate, whilst standing upon the other plane, will not lose all its Electricity, even if it be touched with a finger or with a piece of metal; so that it generally remains so far electrified, as when it is afterwards separated from that plane, it will often afford a small spark, or at least it will affect an electrometer. Indeed this phenomenon could not be explained upon the supposition that the finger or the metals were perfect Conductors: but since we do not know of any perfect Conductor, the metals or the finger oppose a resistance sufficient to retard the immediate dissipation of the Electricity

of

of the plate, which is in that caſe actuated by a very ſmall degree of intenſity or endeavour of expanding; ſo that ſuppoſe, for inſtance, that the piece of metal or the finger, by touching the plate, took off ſo much of its Electricity as to reduce the intenſity of the remainder to the fiftieth part of a degree, this remaining Electricity would then be almoſt nothing; but when the plate, by being ſeparated from the inferior plane, has its capacity ſo far diminiſhed as to render the intenſity of its Electricity one hundred times greater, then the intenſity of that remaining Electricity would become of two degrees, *viz.* ſufficient to afford a ſpark or to affect an electrometer.

Hitherto we have conſidered in what manner the action of electric atmoſpheres muſt modify the Electricity of the metal plate in various ſituations. We muſt now conſider the effects which take place when the Electricity is communicated to the metal plate whilſt ſtanding upon the imperfectly conducting plane; however the explanation of this eaſily follows from what has been ſaid above. Suppoſe, for inſtance, that a

Leyden

Leyden phial or a Conductor were ſo weakly electrified, that the intenſity of its Electricity were only of half a degree, or even leſs; if the metal plate, when ſtanding upon the proper plane, were touched with that phial or Conductor, it is evident that either of them would impart to it a quantity of its Electricity, proportional to the plate's capacity, *viz.* ſo much of it as would make the intenſity of the Electricity of the plate equal to that of the Electricity in the Conductor or phial, ſuppoſed of half a degree; but the plate's capacity, now that it lies upon the proper plane, is above one hundred times greater than if it ſtood inſulated in the air; or, which is the ſame thing, it requires one hundred times more Electricity in order to ſhew the ſame intenſity; therefore, in this caſe, it muſt acquire upwards of a hundred times more Electricity from the phial or Conductor. It naturally follows, that when the metal plate is afterwards removed from the proper plane, its capacity being leſſened ſo as to remain equal to the hundredth part of what it was before, the intenſity of its Electricity muſt become of 50°; ſince, agreeably to the ſuppoſition, the intenſity

intenſity of the Electricity in the phial or Conductor was of half a degree *.

A Conductor that is electrified whilſt ſtanding in full and ample contact with another proper Conductor, or ſemi-inſulating body, as above-mentioned, and is afterwards ſeparated from it, ſhews the ſame phenomena that are exhibited by a Conductor, which, after being electrified, is contracted into a ſmaller bulk, or contrarywiſe, like Dr. FRANKLIN's experiment of the can and chain, &c. †.

If a ſmall quantity of Electricity communicated to the metal plate, whilſt ſtand-

* In a paper on the capacity of ſimple Conductors, Mr. VOLTA, conſidering the great capacity of a Leyden phial, ſhews that the cauſe of it is the Electricity communicated to one of its ſurfaces being balanced by the contrary Electricity of the oppoſite ſurface. He likewiſe proves, that the capacity of ſixteen ſquare inches of coated electric ſurface is equal to the capacity of a Conductor made of ſilvered cylindrical ſticks, nearly one hundred feet long, the capacity of which is ſo great as to afford a ſpark capable of occaſioning a ſhock conſiderably ſtrong.

† See page 331, vol. i. of this work.

ing on the proper plane, will afterwards enable it to give a ſtrong ſpark, it may be aſked, what would a great quantity of Electricity do? The anſwer is, that it would do nothing more; becauſe, when the Electricity communicated to the metal plate is ſo ſtrong as to overcome the ſmall reſiſtance of the inferior plane, it will then be diſſipated.

It will be readily underſtood, that if the metal plate ſituated upon a proper plane can receive a good ſhare of Electricity from a Leyden phial, or from an ample Conductor, however weakly electrified, it cannot receive any conſiderable quantity of it from a Conductor of a ſmall capacity; for this Conductor cannot give what it has not, except it were continually receiving a ſtream, howſoever ſmall, of Electricity, as is the caſe with an atmoſpherical Conductor, or with the prime Conductor of an electrical machine, which acts very poorly, but continues in action. However in ſuch caſe a conſiderable time muſt elapſe before the metal plate has acquired a ſufficient quantity of Electricity.

Thus

Thus much being premiſed relating to the capacity of Conductors, we now proceed to deſcribe Mr. VOLTA's ingenious method of diſcovering, or of rendering ſenſible, the ſmalleſt quantity of Electricity, which is entirely dependent on the foregoing principles.

The method, in ſhort, is to communicate the ſmall, and otherwiſe unobſervable quantity of Electricity to the metal plate of an electrophorus whilſt ſtanding on an imperfectly inſulating plane; for in that ſituation the capacity of the metal plate being augmented, it will acquire an incomparably greater quantity of Electricity than if it ſtood inſulated in the air; and afterwards, when ſeparated from the plane, its capacity will be contracted; and conſequently, its Electricity increaſing at the ſame time, its intenſeneſs will evidently manifeſt itſelf either by ſparks, or, which is the eaſieſt and ſafeſt method, by means of an electrometer.

The particulars neceſſary to be kept in view in this method are the following. The metal plate muſt be at leaſt ſix inches in di-

ameter, with the edge well rounded, and having a varniſhed glaſs handle;—inſtead of a glaſs ſome perſons have uſed three ſilk ſtrings. The inferior plane muſt be of a very imperfect conducting nature, as dry marble, very dry and ſlightly varniſhed wood, a common piece of wood covered with oiled ſilk, or ſuch-like ſubſtance; but let the ſubſtance be what it will, its ſurface muſt be very ſmooth, and ſuch as to coincide as well as poſſible with the ſurface of the metal plate; on which account, if a marble ſlab be choſen for the inferior plane, it will be proper to fit the ſurface of the metal plate to that of the marble, by grinding one againſt the other. What I find to be very fit for this purpoſe is a paper drum, conſiſting of a common wooden hoop, ſuch as are uſed for barrels, over which a piece of thick writing-paper is paſted, on the back of which I paſte a piece of tin-foil. The upper ſurface of the paper is varniſhed only once with ſhell-lac diſſolved in ſpirit of wine. This ſort of plane has many advantages, *viz.* it is eaſily made, and being light is very portable; its ſurface is perfectly plane, excepting indeed when the

hoop

hoop is not very ſtrong, for then the contraction of the paper has power ſufficient to warp it; and laſtly, as the thickneſs of the paper and of the varniſh may be varied at pleaſure, and very eaſily, the ſaid plane may be rendered of any required degree of conducting power.

Now ſuppoſing that an inferior ſemi-conducting plane and a metal plate are properly conſtructed, lay the former upon a table, and upon it lay the latter, taking care that in this operation, or in wiping, &c. the ſurface of the inferior plane be not excited, for that would fruſtrate the experiment *. Then, with the corner of a dry handkerchief, a piece of flannel, of paper, &c. ſtrike five or ſix times the metal plate. Afterwards, laying hold of the glaſs handle, lift up the metal plate from over the inferior plane, and preſenting it to the electrometer you will find that it is evidently electrified. If

* In caſe the ſurface of the inferior plane has acquired any Electricity, either from rubbing it inadvertently, or otherwiſe, the beſt way of freeing it of that Electricity, is to paſs it over the flame of a candle two or three times.

this experiment of ſtriking the plate be repeated when the plate is not on the proper plane, you will find either not the leaſt veſtage of Electricity, or a quantity of it incomparably ſmaller than that obtained in the other way.

By this means, Mr. VOLTA has obtained Electricity not only ſufficient to manifeſt its quality, but even enough to afford ſparks, and that from ſubſtances which could be hardly ſuſpected to be electrified. An atmoſpherical Conductor not much elevated above the top of a houſe, if it be made to communicate with the metallic plate ſtanding on the proper plane (which Mr. VOLTA juſtly calls the *electrical condenſing apparatus)* will be found to be electrified at times in which it would not ſhew any ſigns of Electricity by any other means. Several ſubſtances, even ſome that are conſidered as very good Conductors, will be found to afford a ſenſible quantity of Electricity, when the metal plate of the condenſing apparatus is ſtroked with any of them, ſuch as pieces of cloth, or of leather, moſt green vegetables, and even the human

hand. Indeed there is hardly any ſubſtance, beſides fluids or very ſoft ſubſtances, which will not afford a ſenſible degree of Electricity by this method. But the moſt remarkable diſcoveries made by Mr. VOLTA, are that the evaporation of water and other fluids produces Electricity. Some effervefcences he alſo found to produce Electricity, though their Electricity may be only the conſequence of the evaporation which generally accompanies effervefcences; but before I mention any thing farther relating to thoſe diſcoveries, I ſhall juſt deſcribe two improvements of mine concerning the abovementioned condenſing apparatus.

Obſerving that in ſtroking the metal plate in order to obtain Electricity from various ſubſtances, and eſpecially from the hand, the plate was often moved ſo as to occaſion ſome friction upon the inferior plane, which ſometimes excited that plane in a ſmall degree, and conſequently rendered precarious the reſult of the experiment, I thought of the following improvement, which entirely prevents any motion being communicated to the metal plate.

Upon a varnished glass handle a brass tube about six inches long, and ¾ of an inch in diameter, was cemented, and from the extremity of this tube a fine and very flexible wire proceeded, which was about fourteen inches long. Now when the metal plate was situated upon the inferior plane, I held the glass handle of the brass tube with my left hand, in such a manner as that the end of the wire might touch the plate, the rest remaining in the air. Sometimes, in order to make a better contact, the end of the abovementioned wire was put into a hole purposely made in the edge of the plate. In this disposition of the apparatus the substances to be tried are stroked upon the brass tube, and the Electricity produced by them is conveyed to the metal plate by the wire, which being fine and flexible communicates not the least motion to the said plate.

The other improvement consists in rendering sensible degrees of Electricity still smaller than those, which may be discovered by the above-mentioned condensing apparatus. This improvement was suggested by, and is founded upon, the same principles.

Notwith-

Notwithſtanding the great ſenſibility of this apparatus of Mr. VOLTA, yet ſometimes the Electricity acquired by the metal plate from ſome ſubſtances, was ſo ſmall as not to affect an electrometer ſufficiently to aſcertain its quality, or even its exiſtence; hence I naturally thought that, for the ſame reaſon for which the metal plate of the condenſing apparatus manifeſted ſuch ſmall degrees of Electricity as could not be otherwiſe obſerved, another ſmaller plate, or ſmall condenſing apparatus, might be employed to collect and render ſenſible the weak Electricity of the large metal plate. Accordingly I conſtructed a ſmall plate of about the ſize of a ſhilling, having a glaſs handle covered with ſealing-wax; aud when the large metal plate ſeemed to be ſo weakly electrified as not to affect an electrometer ſenſibly, I placed the ſmall plate upon the inferior plane, and touched it with the edge of the large plate: then, after removing the large plate, I took up the ſmall one from the plane, holding it by the extremity of the glaſs handle, and preſented it to the electrometer, which was generally ſo much affected by it as to diverge to its utmoſt limits.

In this manner I have often obtained Electricity more than sufficient to ascertain its quality, from a single stroke of the corner of a handkerchief: *viz.* the large plate being placed upon the proper plane was stroked once; then being removed and presented to an electrometer, it appeared not electrified, but by touching the small plate with the edge of it, that small plate acquired thereby Electricity sufficient to make an electrometer diverge.

When this secondary condensing apparatus is used, care must be had to hold the large plate almost vertically whilst the small plate is touched with it. There is no need of having another inferior plane for the small plate, the large one being sufficient for both; for immediately after taking up the large plate weakly electrified, with one hand, you lay down the small plate, &c.

The little quantity of Electricity that can be discovered by this means is really surprising; and there is hardly any substance, excepting the metals, or those which cannot be

subjected

ſubjected to trial, as water and other fluids, which will not produce ſome Electricity when rubbed or ſtroked againſt the large plate of the condenſing apparatus, and that Electricity is afterwards condenſed by being communicated to the ſmall plate. In conſequence of thoſe experiments it appears, that throughout the works of nature there is a continual motion of the electric fluid from one ſubſtance to another; ſince there is hardly any friction, and, as it will appear by what follows, any evaporation or condenſation, but it produces Electricity. The extenſive influence of this fluid, or of that power which we call *electric*, and the immenſe dependence of the powers of nature on each other, indicate that Electricity muſt be employed for ſome great operation; but human induſtry has not yet removed the veil from this great myſtery.

The principal diſcovery which Mr. Volta made by means of the condenſing apparatus, is the Electricity produced by the evaporation of water, which explains in a great meaſure, if not entirely, the origin of the

the atmoſpherical Electricity *. He found that water quickly evaporated, that the ſimple combuſtion of coals, and that the effervescence of iron filings, in diluted vitriolic acid, when performed in inſulated veſſels, left the veſſels negatively electrified. This negative Electricity he generally collected and rendered manifeſt by means of the above-deſcribed condenſing apparatus; but ſometimes it is ſo ſtrong as not to require any thing more than a ſenſible electrometer connected with the inſulated veſſel by means of Conductors, as a wire or the like.

The experiment of producing Electricity by the evaporation of water may be eaſily performed, thus—Upon an inſulating ſtand, as a wine glaſs or other electric ſubſtance, place an earthen veſſel, as a crucible, a baſin, or ſuch like thing, and put into it three or four lighted coals. Let a wire be put with one end amongſt the coals, and with the other let it touch a very ſenſible electrometer. (One of my improved atmo-

* This diſcovery was made on the 13th of April, 1782.

ſpherical

ſpherical electrometers, *viz.* that in the bottle, anſwers very well.) Then pour a ſpoonful of water at once upon the coals, which will occaſion a great hiſſing, and a quick evaporation; and at the ſame time you will ſee the electrometer diverge with negative Electricity.

Mr. VOLTA concludes the account of thoſe diſcoveries with the following ingenious remarks. " The experiments," *ſays he*, " hitherto made, though not numerous, " yet concur to ſhew, that the vapours of " water, and in general the parts of all bo- " dies, that are ſeparated by volatilization, " carry away an additional quantity of elec- " tric fluid as well as of elementary heat; " and conſequently that thoſe bodies, from " the contact of which the volatile parti- " cles have been ſeparated, remain both " cooled and electrified negatively: from " which it may be deduced, that whenever " bodies are reſolved into volatile elaſtic " fluid, their capacity for holding electric " fluid is augmented, as well as their ca- " pacity for holding common fire, or the " calorific fluid. This is a ſtriking analogy

" by

“ by which the ſcience of Electricity
“ throws ſome light upon the theory of
“ heat, and alternately derives light from
“ it.

“ By following this analogy it ſeems,
“ that as the vapours on their condenſing
“ loſe part of their latent heat, on account
“ of their capacity being diminiſhed, ſo
“ they part with ſome electric fluid. Hence
“ originates the poſitive Electricity, which
“ is always more or leſs predominant in the
“ atmoſphere, when the ſky is clear, *viz.*
“ at that height where the vapours begin
“ to be condenſed. Accordingly, the at-
“ moſpherical Electricity is ſtronger in fogs,
“ in which caſe the vapours are more con-
“ denſed, ſo as to be almoſt reduced into
“ drops, and is ſtill ſtronger when thick
“ fogs become clouds.

“ Hitherto we have accounted for the
“ poſitive atmoſpherical Electricity; but it
“ is eaſy to account for clouds negatively
“ electrified; for when a cloud, poſitively
“ electrified, has been once formed, its
“ ſphere of action is extended a great way

“ round,

" round, so that if another cloud comes " within that sphere, its electric fluid, " agreeably to the well-known laws of " electric atmospheres, must retire to the " parts of it which are the remotest from " the first cloud; and from thence the " electric fluid may be communicated to " other clouds, or vapours, or terrestrial " prominencies. Thus a cloud may be " electrified negatively, which cloud, after " the same manner, may occasion a positive " Electricity in another cloud, &c. This " explains not only the negative Electricity, " which is often obtained from the atmo- " sphere in cloudy weather, and the fre- " quent changes from positive to negative " Electricity, and contrarywise in stormy " weather, but also the waving motion " often observed in the clouds, and the " hanging down of them, so as nearly to " touch the earth.

" After the fore-mentioned discoveries, " we need no longer wonder at the appear- " ance of lightnings in the eruptions of vol- " canoes, as was particularly observed in the

" late

" late dreadful eruption of Mount Vesuvius.
" The few experiments I have made, shew
" that the quantity of smoke; but much
" more the rapidity with which it is pro-
" duced, tends to increase the Electricity,
" which arises from combustion, &c. How
" great must then be the quantity of Elec-
" tricity that is produced in such erup-
" tions!"

Nº VI.

AN ACCOUNT OF A VERY POWERFUL ELECTRICAL MACHINE, LATELY CONSTRUCTED FOR THE MUSEUM OF TEYLER, AT HARLEM; AND OF VARIOUS EXPERIMENTS MADE WITH IT.

THE deſcription of this machine, and of ſeveral experiments made with it, was written by Mr. VAN MARUM, who has himſelf been the principal operator in thoſe experiments. The various new and intereſting particulars which are mentioned in this deſcription, render it deſerving of being read at large by every lover of philoſophy; and the preſent ſhort extract is intended only to give an idea of it to thoſe who have not the opportunity of peruſing the original, which was lately publiſhed at Harlem.

This machine conſiſts of two circular glaſs plates, each 65 inches in diameter, which being fixed parallel to each other, and

$7\frac{1}{2}$ inches aſunder, on a common axis, are turned by a winch without any accelerated motion, and are rubbed by eight rubbers, all being placed in a proper frame. Each plate is rubbed on both ſurfaces; two cuſhions or rubbers being on one ſide, and two on the oppoſite ſide of each plate. The prime Conductor is divided into branches, which enter between the plates, and, by means of points, collect the electric fluid only from their inner ſurfaces.

In general two men are employed to work this machine, but when it is required to keep it in action for a long time, then four men are put to it.

The power of this machine appears to be greater than that of any other made before, and indeed its effects are ſurpriſing. I ſhall only enumerate them as briefly as poſſible, without expatiating on the points of compariſon between them and others of a ſimilar nature, performed with other machines.

A very ſharp ſteel point, being preſented to the prime Conductor, drew a luminous

ſtream of electric fluid, about half an inch long.

When a ſharp ſteel point was fixed to the Conductor, ſo as to project three inches from it, on working the machine the point threw out ſtreams of light, which were ſix inches long when a ball of three inches in diameter was preſented to it; and only two inches long when another point was preſented inſtead of the ball.

The ſenſation, commonly called the ſpider's web, on the face of the by-ſtanders, when this machine is in action, is often felt at the diſtance of eight feet from the prime Conductor.

A thread ſix feet long, ſuſpended perpendicularly, was ſenſibly attracted by the prime Conductor at the diſtance of thirty-eight feet. This attraction of the thread by the prime Conductor was ſuch as juſt to make the thread deviate from the perpendicular direction. A pointed wire, preſented to the Conductor, appeared luminous, even when the diſtance between the former and the latter was twenty-eight feet.

Another Conductor being presented to the prime Conductor, in order to receive the sparks from it, and a perfect metallic communication being made between the former and the earth, by means of a long brass wire $\frac{3}{8}$ of an inch in diameter; it was found, that whilst a stream of electric fluid went from the prime Conductor to the other, which may be called the *receiving Conductor*, the brass wire gave small sparks to conducting bodies that were placed near it. The quantity of electric fluid, accumulated by this machine and discharged by the prime Conductor, must have been really surprisingly great; since a wire of $\frac{3}{8}$ of an inch in diameter was not capable of transmitting it to the earth very easily. The sparks between the two Conductors were generally 21, but sometimes 24 inches long. The stream of fire was crooked, and darted many lateral brushes of a very large size.

Gunpowder, after the manner formerly used by Mr. WILSON, as it is mentioned in the preceding pages, and some other combustibles, were fired at the prime Conductor of this machine.

A single

A single spark from the Conductor melted a considerable length of gold-leaf.

A Leyden phial, containing about one square foot of coated surface, was fully charged by about half a turn of the winch, so as to discharge itself; and by repeated trials it was found, that in one minute's time this phial discharged itself 76, 78, and often 80 times.

By many repeated experiments, accurately made by Mr. VAN MARUM, and other ingenious persons, with this machine, it was found, that electrization, whether positive or negative, did neither sensibly augment nor diminish the natural number of pulsations in a man *.

They

* In my Essay on Medical Electricity it is mentioned, that from the experience of many it appeared, that Electrization increases the number of pulsations about one-sixth; but having made several experiments upon myself, I added the following observation in the second edition of the said Essay, which was published in the year 1781, and consequently long before Mr. VAN MARUM's experiments. "I do not remember that "my pulse was ever evidently accelerated by electri- "zation,

They wished to try the effect of taking the electric sparks in different sorts of elastic fluids, and for this purpose, they used a cylindrical glass receiver, five inches long, and an inch and a quarter in diameter, into which different sorts of elastic fluids were successively inserted, and were confined by quicksilver or water. To a hole made in the bottom of the inverted glass receiver an iron wire was fastened, the external part of which communicated with a Conductor, which, being presented to the prime Conductor of the machine, received the sparks from it. In this disposition of the apparatus it evidently appears, that the sparks passed through the elastic fluid contained in the receiver, by going from the inner extre-

"zation, and yet I have repeated the experiment various times, and with great diversity of circumstances." P. 15.—Upon the whole therefore it seems to be ascertained, that electrization does not accelerate nor retard the ordinary number of pulsations, and that the augmentation generally observed before must have been owing to fear or apprehension. But I am informed by Mr. PARTINGTON, who has long practised medical Electricity, that electrization, if not in a sound, at least in an unsound state of the body, augments the number of pulsations considerably.

mity of the wire to the quickſilver or water in which the receiver was inverted. With this apparatus it was found, that dephlogiſticated air, obtained from mercurial red precipitate, loſt $\frac{1}{20}$ of its bulk, but its quality was not ſenſibly altered, as it appeared from examining it with the eudiometer. This experiment being repeated when the receiver was inverted in lime-water, and likewiſe in the infuſion of turnſole, there enſued no precipitation, no change of colour, nor any phlogiſtication of the air. On pouring out this air, the uſual ſmell of the electric fluid was perceived very ſenſibly.

Nitrous air was diminiſhed of more than the half of its original bulk, and in that diminiſhed ſtate, being mixed with common air, it occaſioned no red colour, nor any ſenſible diminution. It had loſt its uſual ſmell, and it extinguiſhed a candle. In paſſing the ſparks through the nitrous air, a powder is formed on the ſurface of the quickſilver, which is a part of that metallic ſubſtance diſſolved by the nitrous acid.

Inflammable air, obtained from iron and

diluted vitriolic acid, communicated a little redneſs to the tincture of turnſole. The ſtream of electric fluid through this air appeared more red, and much larger, than in common air, being every where ſurrounded by a faint blue light.

The inflammable air, obtained from ſpirit of wine and vitriolic acid, was increaſed to about three times its original bulk, and loſt a little of its inflammability.

Fixed air, from chalk and vitriolic acid, was a little increaſed in bulk by the action of Electricity; but it was rendered leſs abſorbible by water.

Vitriolic acid air, obtained from vitriolic acid and charcoal, was diminiſhed a little, and black ſpots were formed on the inſide of the glaſs receiver. Afterwards it was obſerved, that only one-eighth part of the electrified elaſtic fluid was abſorbed by water. It extinguiſhed a candle, and had very little ſmell.

Marine acid air ſeemed to oppoſe in great

meaſure

measure the passage of the electric fluid; since the sparks would not pass through a greater length than 2¼ inches of this air. It was considerably diminished, but the rest was readily absorbed by water.

Spathous air was neither diminished, nor any other way sensibly altered, by the electric sparks.

Alkaline air, extracted from spirit of sal ammoniac, was at first almost doubled in bulk; then it was diminished a little; after which it remained without any augmentation or diminution. It became unabsorbible by water, and by the contact of flame it exploded, like a mixture of inflammable air and a good deal of common air.

Common air was lastly tried, and it was found to give a little faint redness to the tincture of turnsole; becoming at the same time sensibly phlogisticated. The experiment was repeated thrice at different times, and each time after the electrization it was examined by the admixture of nitrous air in Mr. FONTANA's eudiometer, and it

was

was compared with the ſame air not electrified; the latter always ſuffering the greateſt diminution. In the firſt experiment the diminutions were $\frac{145}{500}$ and $\frac{175}{500}$; in the ſecond, $\frac{159}{500}$ and $\frac{194}{500}$; and in the laſt, $\frac{149}{500}$ and $\frac{178}{500}$.

The experiments laſtly deſcribed by Mr. VAN MARUM, were made with a large battery, which was charged by the abovementioned machine. The battery conſiſted of 135 coated phials, all together containing about 130 ſquare feet of coated ſurface; and it was generally charged to the full, by about 100 turns of the glaſs plates of the machine. This battery appears to have had a much greater power than what was ever obtained before by any inſtrument of the kind. With it they melted an iron wire, 15 feet long, and $\frac{1}{151}$ of an inch in diameter; and another time they melted an iron wire, 25 feet long, and $\frac{1}{240}$ of an inch in diameter.

With this extraordinary power of accumulated Electricity, they tried to give magnetiſm to needles made out of watch-ſprings, which

which were three and even fix inches in length; and alfo to fteel bars of nine inches in length, from a quarter to half an inch broad, and about a twelth of an inch thick. Here follows the refult of thofe experiments.

When the bar or needle was placed horizontally in the magnetic meridian, whichever way the fhock entered, the end of the bar that ftood towards the north acquired the north polarity, or the power of turning towards the north when freely fufpended, and the oppofite end acquired the fouth. If the bar, before it received the fhock, had fome polarity, and was placed with its poles contrary to the ufual direction, then its natural polarity was always diminifhed, and often reverfed, fo that the extremity of it, which in receiving the fhock looked towards the north, became the north pole, &c.

When the bar or needle was ftruck ftanding perpendicularly, its loweft end became the north pole in any cafe, even when the bar had fome magnetifm before, and was placed with

with the ſouth pole downwards. All other circumſtances being alike, the bars ſeemed to acquire an equal degree of magnetic power, whether they were ſtruck whilſt ſtanding horizontally in the magnetic meridian, or perpendicular to the horizon.

When a bar or needle was placed in the magnetic equator, whichever way the ſhock entered never gave it any magnetiſm; but if the ſhock was given through its width, then the needle acquired a conſiderable degree of magnetiſm, and the end of it which laid towards the weſt became the north pole, and the other end the ſouth pole.

If a needle or bar, already magnetic, or a real magnet, was ſtruck in any direction, its power was always diminiſhed. For this experiment, they tried conſiderably large bars; one being 7,08 inches long, 0,26 broad, and 0,05 thick.

When the ſhock was ſo ſtrong, in proportion to the ſize of the needle, as to render it hot, then the needle generally acquired no magnetiſm at all, or very little.

The

The experiments laſtly tried with this very powerful battery, were concerning the calcination of metallic ſubſtances, and the revivification of their calces. It appears that the electric ſhock produced both theſe apparently contradictory effects.

The metallic calces uſed in thoſe experiments were of the pureſt ſort; they were confined between glaſſes, whilſt the ſhock was paſſed over them. By this means the calces were ſo far revivified as to exhibit ſeveral grains of the metal, large enough to be diſcerned by the naked eye, and to be eaſily ſeparated from the reſt.

As to the calcination of metals, whenever a ſhock was employed much greater than that which was neceſſary to fuſe the metal, part of the metal was calcined, and diſperſed into ſmoke. It is remarkable, that this calcination or ſmoke generally produced ſeveral filaments, of various lengths and thickneſſes, which ſwam in the air. It was farther obſerved, that thoſe flying filaments of metallic calx, if a Conductor was preſented to them, were ſoon attracted by it; but after the

firſt

first contact they were instantly repelled, and generally broke into diverse parts.

Thus far of this extraordinary machine, to which I shall only add a wish, that machines still larger may be attempted by the opulent and the ingenious; for since this powerful machine has shewn several particulars both new and interesting, it is very probable that larger machines, and farther experiments, will discover more of the hidden secrets of nature.

Nº VII.

OF THE ELECTRIC PROPERTIES OF THE TORPEDO, GYMNOTUS ELECTRICUS, AND SILURUS ELECTRICUS.

THE electric power, by the ancients obferved only in amber, and perhaps in the tourmalin, was in procefs of time found to be produced by glafs, fulphur, refins, filk, and diverfe other bodies. It has been within thefe fifty years that its great influence has been difcovered in the atmofphere; and not yet thirty years fince that power has been obferved even in the animal kingdom. Three fifhes have hitherto been difcovered to have the fingular property of giving fhocks analogous to thofe of artificial Electricity, namely, the *torpedo*, the *gymnotus electricus*, and the *filurus electricus*.

The ancients indeed were acquainted with this wonderful property of the firft, and

probably of the laſt of thoſe animals, and it was from the property of giving that ſhock, benumbing ſenſation, or *torpor*, that they called the firſt *torpedo*; but they were utterly ignorant of the cauſe of it. Two diſtinguiſhed writers of the laſt century, endeavoured to explain this property upon mechanical laws, but their ingenuity was inſufficient to account for the phenomenon.

The principal diſcoveries, relating to the identity of the above-mentioned property of thoſe fiſhes and the electric ſhock, were made by JOHN WALSH, Eſq. F. R. S. to whoſe ingenuity we are indebted for the demonſtration of the power of the torpedo agreeing with the electric ſhock in all the points of compariſon in which it could be examined; and alſo for almoſt all the other diſcoveries which were ſince made relating to thoſe animals.

The three animals which, whilſt alive, are poſſeſſed of an electric power, are belonging to three different orders of fiſh; and the few particulars, which they ſeem to have in common, are the power of giving the ſhock;

an organ in their body, now called the *electric organ*, which is employed by the animals for the exertion of that power; a ſmooth ſkin without ſcales; and ſome ſpots here and there on the ſurface of their bodies.

The torpedo, which belongs to the order of *rays*, is a flat fiſh, very ſeldom twenty inches in length, weighing not above a few pounds when full grown, and pretty common in various parts of the ſea-coaſt of Europe. The electric organs of this animal are two in number, and placed one on each ſide of the cranium and gills, reaching from thence to the ſemicircular cartilages of each great fin, and extending longitudinally from the anterior extremity of the animal to the tranſverſe cartilage which divides the thorax from the abdomen. In thoſe places they fill up the whole thickneſs of the animal from the lower to the upper ſurface, and are covered by the common ſkin of the body, under which, however, are two thin membranes or *faſciæ*. The length of each organ is ſomewhat leſs than one-third part of the length of the whole animal. Each organ conſiſts of perpendicular columns, reaching

from the under to the upper ſurface of the body, and varying in length according to the various thickneſs of the fiſh in various parts. The number of thoſe columns is not conſtant, being not only different in different torpedos, but likewiſe in different ages of the animal, new ones ſeeming to be produced as the animal grows. In a very large torpedo one electric organ was found to conſiſt of 1182 columns. The greateſt number of thoſe columns are either irregular hexagons, or irregular pentagons, but their figure is far from being conſtant. Their diameters are generally one-fifth part of an inch. "Their coats are very thin, and ſeem tranſparent, cloſely connected with each other, having a kind of looſe net-work of tendinous fibres paſſing tranſverſely and obliquely between the columns, and uniting them more firmly together: theſe are moſtly obſervable where the large trunks of the nerves paſs. The columns are alſo attached by ſtrong inelaſtic fibres, paſſing directly from the one to the other."

"Each column is divided by horizontal partitions, placed over each other at very

ſmall diſtances, and forming numerous interſtices, which appear to contain a fluid. Theſe partitions conſiſt of a very thin membrane, conſiderably tranſparent. Their edges appear to be attached to one another, and the whole is attached by a fine cellular membrane to the inſide of the columns. They are not totally detached from one another: I have found them adhering at different places, by blood-veſſels paſſing from one to another."

"The number of partitions contained in a column of one inch in length, of a torpedo which had been preſerved in proof ſpirit, appeared, upon a careful examination, to be one hundred and fifty: and this number, in a given length of column, appears to be common to all ſizes in the ſame ſtate of humidity, for by drying they may be greatly altered; whence it appears probable that the increaſe in the length of the column, during the growth of the animal, does not enlarge the diſtance between each partition in proportion to that growth; but that new partitions are formed, and added to the extremity of the column from the *faſcia*."

"The partitions are very vaſcular; the arteries are branches from the veins of the gills, which convey the blood that has received the influence of reſpiration. They paſs along with the nerves to the electric organ, and enter with them; then they ramify in every direction, into innumerable ſmall branches upon the ſides of the columns, ſending in from the circumference all around, upon each partition, ſmall arteries, which ramify and anaſtomoſe upon it; and paſſing alſo from one partition to another, anaſtomoſe with the veſſels of the adjacent partitions."

"The veins of the electric organ paſs out cloſe to the nerves, and run between the gills, to the auricle of the heart."

"The nerves inſerted into each electric organ ariſe by three very large trunks from the lateral and poſterior part of the brain. The firſt of theſe, in its paſſage outwards, turns round a cartilage of the *cranium*, and ſends a few branches to the firſt gill, and to the anterior part of the head, and then paſſes into the organ towards its anterior extremity.

mity. The ſecond trunk enters the gills between the firſt and ſecond opening, and, after furniſhing it with ſmall branches, paſſes into the organ near its middle. The third trunk, after leaving the ſkull, divides itſelf into two branches, which paſs to the electric organ through the gills; one between the ſecond and third openings, the other between the third and fourth, giving ſmall branches to the gill itſelf. The nerves having entered the organs, ramify in every direction, between the columns, and ſend in ſmall branches upon each partition, where they are loſt."

"The magnitude and the number of the nerves beſtowed on theſe organs, in proportion to their ſize, muſt on reflection appear as extraordinary as the phenomena they afford. Nerves are given to parts either for ſenſation or for action. Now if we except the more important ſenſes of ſeeing, hearing, ſmelling, and taſting, which do not belong to the electric organs, there is no part, even of the moſt perfect animal, which, in proportion to its ſize, is ſo liberally ſupplied with nerves; nor do the nerves ſeem neceſ-

ſary for any ſenſation which can be ſuppoſed to belong to the electric organs: and, with reſpect to action, there is no part of any animal, with which I am acquainted, however ſtrong and conſtant its natural actions may be, which has ſo great a proportion of nerves *."

Thus far with the anatomical deſcription of the animal; we ſhall now proceed to deſcribe its wonderful electric properties.

The above-mentioned electric organs ſeem to be the only parts employed to produce the ſhock; the reſt of the animal appearing to be only the Conductor of that ſhock, as parts adjacent to the electric organs; and, in fact, by artificial Electricity, it has been found that the animal is a Conductor of the electric fluid. The two great lateral fins which bound the electric organs laterally, are the beſt Conductors.

If the torpedo, whilſt ſtanding in water or out of the water, but not inſulated, be

* Mr. HUNTER's anatomical obſervations on the torpedo. Phil. Tranſ. vol. LXIII.

touched

touched with one hand, it generally communicates a trembling motion or ſlight ſhock to the hand, but this ſenſation is only felt in the fingers of that hand. If the torpedo be touched with both hands at the ſame time, one hand being applied to its under, and the other to its upper ſurface a ſhock in that caſe will be received, which is exactly like that occaſioned by the Leyden phial. When the hands touch the fiſh on the oppoſite ſurfaces, and juſt over the electric organs, then the ſhock is the ſtrongeſt; but if the hands be placed in other parts of the oppoſite ſurfaces, the ſhocks are ſomewhat weaker, and no ſhock at all is felt when the hands are both placed upon the electric organs of the ſame ſurface; which ſhews that the upper and lower ſurfaces of the electric organs are in oppoſite ſtates of Electricity, anſwering to the *plus* and *minus* ſides of a Leyden phial. When the fiſh is touched by both hands on the ſame ſurface, and the hands are not placed exactly on the electric organs, a ſhock though weak is ſtill received, but in that caſe the oppoſite power of the other ſurface of the animal ſeems to be conducted over the ſkin.

 The

The ſhock given by the torpedo when in air is about four times as ſtrong as when in water; and when the animal is touched on both ſurfaces by the ſame hand, the thumb being applied to one ſurface, and the middle finger to the oppoſite ſurface, the ſhock is felt much ſtronger than when the circuit is formed by both hands. Sometimes the torpedo gives the ſhocks ſo quickly one after the other, that ſcarcely two ſeconds elapſe between them; and when, inſtead of a ſtrong determined ſtroke, it communicates only a *torpor*, that ſenſation is juſtly attributed to the ſucceſſive and quick diſcharge of many conſecutive ſmall ſhocks. It is very ſingular, that the torpedo, even when inſulated, ſhould be capable of giving a great many ſhocks to perſons likewiſe inſulated.

This power of the torpedo is conducted by the ſame ſubſtances which conduct Electricity, and is interrupted by the ſame ſubſtances which are not Conductors of Electricity: hence if the animal, inſtead of being touched immediately with the hands, be touched by non-electrics, as wires, two

wet cords, or other Conductors of Electricity, held in the hands of the experimenter, the ſhock will alſo be communicated through them. The circuit may alſo be formed by ſeveral perſons joining hands, and the ſhock will be felt by them all at the ſame time. When the animal is in water, if the hands are put in the water, a ſhock will alſo be felt, which will be ſtronger if one of the hands be brought quite into contact with the fiſh, whilſt the other hand is kept in the water at a diſtance from it. In ſhort, the ſhock of this animal is conducted by the ſame Conductors which conduct that of a Leyden phial. This ſhock of the torpedo may be alſo conducted by ſeveral circuits at once, and the circuit may be conſiderably extended; but the ſhock is always weakened by lengthening or multiplying the circuit.

The ſhock of the torpedo cannot paſs through the leaſt interruption of continuity in the Conductors which form the circuit; ſo that it will not be conducted by a chain, nor will it paſs through the air from one Conductor to the other, when the diſtance between

between them is even leſs than the two hundredth part of an inch; conſequently no ſpark has ever been obſerved to accompany it.

No electric attraction or repulſion could be ever obſerved to be produced by the torpedo, nor, indeed, by any of the electric fiſhes; though ſeveral experiments bave been purpoſely made with them.

Theſe ſhocks of the torpedo ſeem to depend on the will of the animal; for each effort is accompanied with a depreſſion of his eyes, by which even his attempts to give it to non-conductors may be obſerved. It is not known whether both electric organs muſt always act together, or only one of them may be occaſionally put in action by the will of the animal.

All theſe effects of the torpedo may be imitated by means of a large electric battery weakly charged, and furniſhed with Mr. Lane's electrometer, the balls of which muſt be put exceedingly near, or almoſt in contact with each other. But the properties of the gymnotus electricus, which we are going to deſcribe next, will throw

more light on thoſe of the torpedo, and will ſhew much more evidently their analogy with the power of the electric fluid diſperſed through a vaſt ſurface of coated electric ſubſtance. "But," ſays Mr. Walsh, "after "the diſcovery that a large area of rare "Electricity would imitate the effect of the "torpedo, it may be inquired, where is "this large area to be found in the animal? "we here approach to that veil of nature, "which man cannot remove. This, how- "ever, we know, that from infinite diviſion "of parts infinite ſurface may ariſe, and "even our groſs optics tell us, that thoſe "ſingular organs, ſo often mentioned, con- "ſiſt, like our electric batteries, of many "veſſels, call them cylinders or hexagonal "priſms, whoſe ſuperficies taken together "furniſh a conſiderable area *."

The gymnotus electricus has been frequently called *electrical eel,* on account of its ſuperficial reſemblance to the common eel; though, when accurately examined, it is found to have none of the ſpecific properties of that animal. The gymnotus is found

* Phil. Tranſ. vol. LXIII. p. 476.

pretty

pretty frequently in the great rivers of South America. Its uſual length is about three feet; but it has been ſaid that ſome of them have been ſeen ſo large, as to be able to ſtrike a man dead with the ſhock of their electric organs. A few of theſe animals were brought to England about eighteen years ago, which, as far as I know, were the firſt of the kind brought to Europe. They had been catched in Surinam river, a great way above where the ſalt-water reaches. It was with thoſe identical fiſhes that Mr. WALSH made many diſcoveries relating to their electrical properties, and the experiments which ſhew thoſe properties were publicly exhibited in London, during ſeveral months.

The ſubject of Animal Electricity was conſiderably advanced by the diſcovery of the ſpark, with which the ſhock of the gymnotus was attended; for, notwithſtanding the previous diſcoveries relating to the torpedo, and the actual poſſibility of imitating the effects of that animal's extraordinary power by means of a large battery weakly charged with artificial Electricity, yet the ſcrupulous philoſophers ſtill ſuſpected that the power of the torpedo might be ſomething different

ent from Electricity, since the two principal characteristics of Electricity, namely, the spark and the attraction, had never been discovered in the torpedo; and at the same time it was difficult to conceive the manner in which the electic fluid might be generated, accumulated, and discharged in an animal, which, at least in its usual state of existence, is a Conductor of Electricity, and is surrounded by a fluid which is likewise a Conductor of that power. This indeed still remains a profound secret; and it is difficult to say, whether any future experiments will ever disclose it. But the spark having been discovered with the gymnotus, the analogy between its power and Electricity is rendered considerably more evident, and it would be scepticism to doubt of the property of the torpedo being derived from the same cause as that of the gymnotus.

In order to proceed regularly, I shall now begin with the description of the animal, and shall then enumerate its electric properties, in a very concise manner.

A gymnotus of three feet length, is generally

rally between ten and fourteen inches in circumference, about the thickeſt part of its body. The electric power of this animal being much greater than that of the torpedo, its electric organs are accordingly a great deal larger, and indeed that part of its body which contains moſt of the animal parts, or the parts common to the ſame order of fiſhes, is conſiderably ſmaller than that which is ſubſervient to the electric power; though the latter muſt naturally derive nouriſhment and action from the former.

The head of the animal is large, broad, flat, ſmooth, and impreſſed with various ſmall holes. The mouth is rather large, but the jaws have no teeth, ſo that the animal lives by ſuction, or by ſwallowing the food entire. The eyes are ſmall, flattiſh, and of a bluiſh colour, placed a little way behind the noſtrils. The body is large, thick, and roundiſh for a conſiderable diſtance from the head, and then diminiſhes gradually. The whole body, from a few inches below the head, is diſtinguiſhed into four longitudinal parts, clearly divided from each other by lines. The carina begins a few

few inches below the head, and widening as it proceeds, reaches as far as the tail, where it is thinneſt. It has two pectoral fins, and the *anus* is ſituated on the under part, more forward than thoſe fins, and of courſe not far diſtant from the *roſtrum*.

This animal has two pairs of electric organs, one pair being larger than the other, and occupying moſt of the longitudinal parts of the body. They are divided from each other by peculiar membranes. "The ſtructure of theſe organs is extremely ſimple and regular, conſiſting of two parts, *viz.* flat partitions or *ſepta*, and croſs diviſions between them. The outer edges of theſe *ſepta* appear externally in parallel lines nearly in the direction of the longitudinal axis of the body. Theſe *ſepta* are thin membranes placed nearly parallel to one another: their lengths are nearly in the direction of the long axis, and their breadth is nearly the ſemidiameter of the body of the animal. They are of different lengths, ſome being as long as the whole organ. I ſhall deſcribe them as beginning principally at the anterior end of the organ, although a few begin

along

along the upper edge; and the whole, paſſing towards the tail, gradually terminate on the lower ſurface of the organ, the lowermoſt at their origin terminating ſooneſt. Their breadths differ in different parts of the organ. They are in general broadeſt near the anterior end, anſwering to the thickeſt part of the organ, and become gradually narrower towards the tail; however, they are very narrow at their beginnings or anterior ends. Thoſe neareſt to the muſcles of the back are the broadeſt, owing to their curved or oblique ſituations upon theſe muſcles, and grow gradually narrower towards the lower parts; which is in a great meaſure owing to their becoming more tranſverſe, and alſo to the organ becoming thinner at that place. They have an outer and an inner edge: the outer is attached to the ſkin of the animal, to the lateral muſcles of the fin, and to the membrane which divides the great organ from the ſmall; and the whole of their inner edges are fixed to the middle partition, to the air bladder, and three or four terminate on that ſurface which incloſes the muſcles of the back. Theſe *ſepta* are at the greateſt diſtance from one another at their exterior

edges

edges, near the ſkin, to which they are united; and as they paſs from the ſkin towards their inner attachments they approach one another: ſometimes we find two uniting in one. On that ſide next to the muſcles of the back they are hollow from edge to edge, anſwering to the ſhape of thoſe muſcles, but become leſs and leſs ſo towards the middle of the organ; and from that towards the lower part of the organ they become curved in the other direction. At the anterior part of the large organ, where it is nearly of an equal breadth, they run pretty parallel to one another, and alſo pretty ſtraight; but where the organ becomes narrower, it may be obſerved in ſome places that two join or unite into one, eſpecially where a nerve paſſes acroſs. The termination of this organ at the tail is ſo very ſmall, that I could not determine whether it conſiſted of one *ſeptum* or more. The diſtances between theſe *ſepta* will differ in fiſhes of different ſizes. In a fiſh of two feet four inches in length I found them $\frac{1}{27}$ of an inch diſtant from one another, and the breadth of the whole organ, at the broadeſt part, about an inch and a quarter, in which ſpace were 34 *ſepta*. The ſmall organ has the ſame

 kind

kind of *septa*, in length passing from end to end of the organ, and in breadth passing quite across, they run somewhat serpentine, not exactly in straight lines. Their outer edges terminate on the outer surface of the organ, which is in contact with the inner surface of the external muscle of the fin, and their inner edges are in contact with the centre muscles. They differ very much in breadth from one another; the broadest being equal to one side of the triangle, and the narrowest scarcely broader than the point or edge. They are pretty nearly at equal distances from one another; but much nearer than those of the large organ, being only about $\frac{1}{56}$ part of an inch asunder: but they are at a greater distance from one another towards the tail, in proportion to the increase of breadth of the organ. The organ is about half an inch in breadth, and has fourteen *septa*: these *septa*, in both organs, are very tender in consistence, being easily torn; they appear to answer the same purpose with the columns in the *torpedo*, making walls or butments for the subdivisions, and are to be considered as making so many distinct organs. These *septa* are intersected transversely by very thin plates of mem-

 branes,

branes, whose breadth is the distance between any two *septa*, and therefore of different breadths in different parts; broadest at that edge which is next to the skin, narrowest at that next to the centre of the body, or to the middle partition which divides the two organs from one another. Their lengths are equal to the breadths of the *septa* between which they are situated: there is a regular series of them continued from one end of any two *septa* to the other; they appear to be so close as even to touch. In an inch in length there are about 240, which multiplies the surface in the whole to a vast extent *."

The nerves which go to the electric organs of the gymnotus, as well as of the torpedo, are much larger than those which supply any other part of the body. The electric organs of the gymnotus are supplied with nerves from the spinal marrow, and they come out in pairs between the vertebræ of the spine.

* Mr. HUNTER's account of the Gymnotus Electricus. Phil. Transf. Vol. LXV.

The gymnotus possesses all the electric properties of the torpedo, but in a superior degree. His shock is conducted by the Conductors of Electricity, and interrupted by the non-conductors of the electric fluid. Hence the shock is communicated through water, without the immediate contact of the animal, or through any other proper circuit; but the stronger shock is received by touching the animal when out of the water; and the best way to receive strong shocks, is to apply one hand towards the tail, and the other towards the head of the animal. In this manner I have often received shocks, which I felt not only in my arms, but even very forcibly in my breast. If the animal be touched only with one hand, then a kind of tremor is felt in that hand only, which though stronger, is quite analogous to the sensation communicated by the torpedo when touched in the like manner. The gymnotus's power of giving shocks is also depending on the will of the animal, so that sometimes he gives very strong shocks, and at other times very weak ones, but he gives the strongest shocks when provoked by being frequently and roughly touched.

When

When ſmall fiſhes are put into the water wherein the gymnotus is kept, they are generally ſtunned or killed by a ſhock, and then they are ſwallowed, if the animal is hungry. The fiſhes which are ſtunned by the gymnotus, may often be recovered by being ſpeedily removed into another veſſel of water.

The ſtrongeſt ſhocks of the gymnotus will paſs a very ſhort interruption of continuity in the circuit. Thus they will be conducted by a chain, eſpecially when it is not very long, and is ſtretched, ſo as to bring its links into better contact. When the interruption is formed by the inciſion made by a pen-knife on a ſlip of tin-foil that is paſted on glaſs, and that ſlip is put into the circuit, the ſhock in paſſing through that interruption, will ſhew a ſmall but vivid ſpark, plainly diſtinguiſhable in a dark room.

Mr. Walsh made another remarkable diſcovery with the gymnotus, which he ſhewed at his houſe to various ingenious perſons: it was a new ſort of ſenſe in the animal, by which he knew when the bodies which

which came near him, were ſuch as could receive the ſhock (*viz.* Conductors) and when they were of the contrary nature; in the former of which caſes the animal gave the ſhock, but not in the latter. In order to ſhew this wonderful property, divers experiments were made, but the moſt convincing one was the following:—the extremities of two wires were dipped into the water of the veſſel wherein the animal was kept, then they were bent, and extended a great way, and laſtly terminated in two ſeparate glaſſes full of water. Theſe wires being ſupported by non-conductors at a conſiderable diſtance from each other, it is plain that the circuit was not complete: but if a perſon put the fingers of both his hands into the glaſſes wherein the wires terminated, *viz.* thoſe of one hand into one, and thoſe of the other hand into the other glaſs, then the circuit became complete. Now it was conſtantly obſerved, that whilſt the above-deſcribed circuit remained interrupted, the animal never went purpoſely near the extremities of the wires, as he uſed to do when willing to give the ſhock: but the moment that the circuit was completed, either by a perſon or any other Conductor, the animal immediately

went

went towards the wires, and gave the ſhock; though the completion of the circuit was performed quite out of his ſight.

Several other particulars, not only concurring to prove the above-mentioned property, but otherwiſe intereſting, were aſcertained by Mr. WALSH; but for theſe we muſt wait till that ingenious gentleman will favour the public with a particular account of his reſearches.

The third fiſh which is known to have the power of giving the ſhock, is found in the rivers of Africa, but we have a very imperfect account of its properties *.

This animal belongs to the order which the naturaliſts call *ſilurus*; hence it is commonly called *ſilurus electricus*. Some of thoſe fiſhes have been ſeen even above twenty inches long.

* Meſſrs ADANSON and FORSKAL make a ſhort mention of it; and Mr. BROUSSONET deſcribes it, under the French name of *le Trembleur*, in the Hiſt. de l'Academie Royale des Sciences, for the year 1782.

The

The body of the ſilurus electricus is oblong, ſmooth, and without ſcales; being rather large, and flattened towards its anterior part. The eyes are of a middle ſize, and are covered by the ſkin, which envelopes the whole head. Each jaw is armed with a great number of ſmall teeth. About the mouth it has ſix filamentous appendices, *viz.* four from the under lip, and two from the upper; the two external ones, or farthermoſt from the mouth on the under lip, are the longeſt. The colour of the body is greyiſh, and towards the tail it has ſome blackiſh ſpots.

The electric organ ſeems to be towards the tail, where the ſkin is thicker than on the reſt of the body, and a whitiſh fibrous ſubſtance, which is probably the electric organ, has been diſtinguiſhed under it.

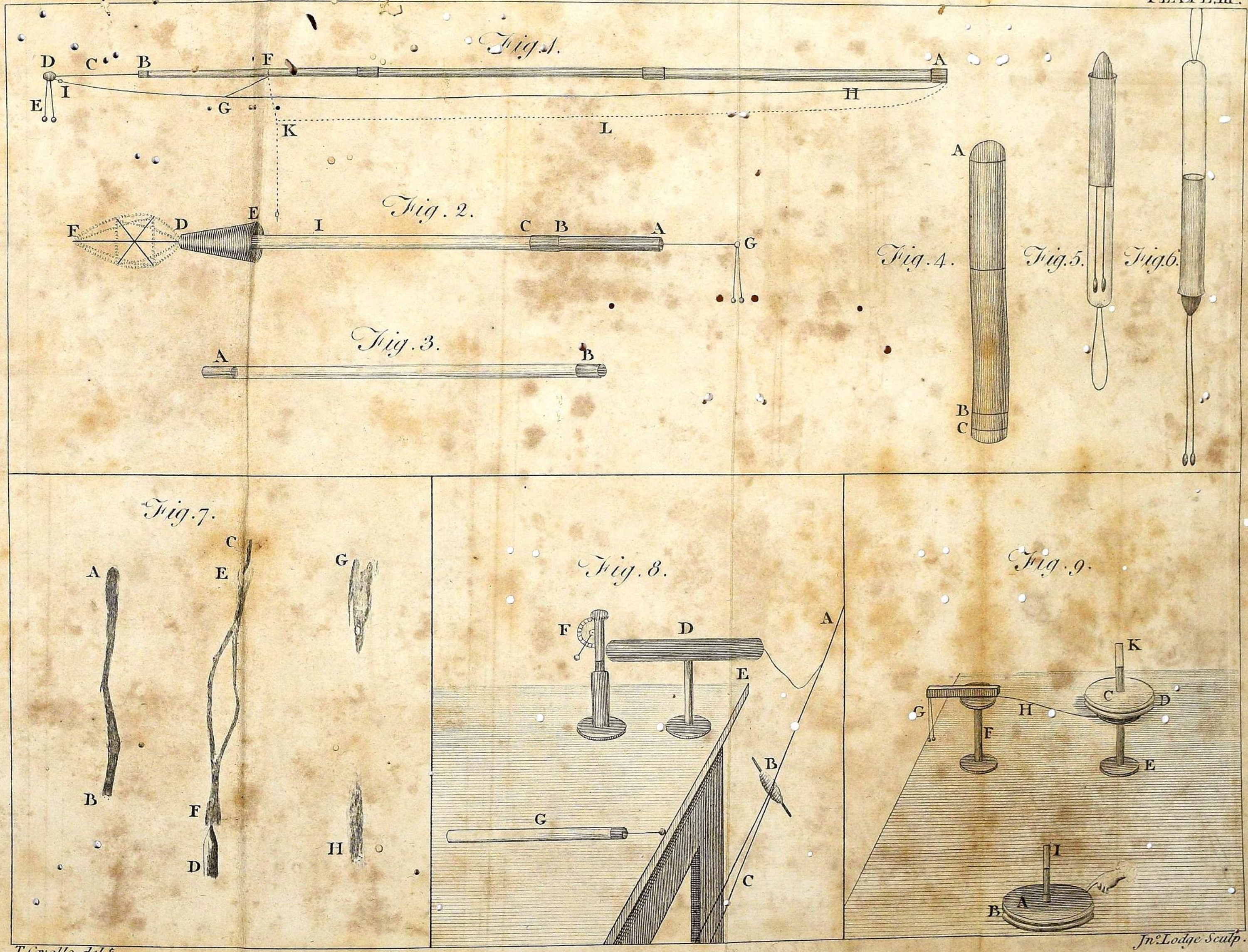
It is ſaid that the ſilurus electricus has the property of giving a ſhock or benumbing ſenſation like the torpedo, and that this ſhock is communicated through ſubſtances that are conductors of Electricity; but no other particular about it is known with any conſiderable degree of certainty.

An inquisitive mind will immediately enquire, for what purpose has nature furnished those animals with so singular a property. But the present knowledge of the subject seems to furnish no other answer, except, that they are endowed with the power of giving the shock for the sake of securing their prey, by which they must subsist, and perhaps of repelling larger animals, which might otherwise annoy them.

The ancients considered the shocks given by the torpedo as capable of curing various disorders; and a modern philosopher will hardly hesitate to believe their assertions, after that Electricity has been found to be a remedy for many diseases.

END OF VOL. II.

Plate. III.



T. Cavallo del.^t

Jno Lodge Sculp.

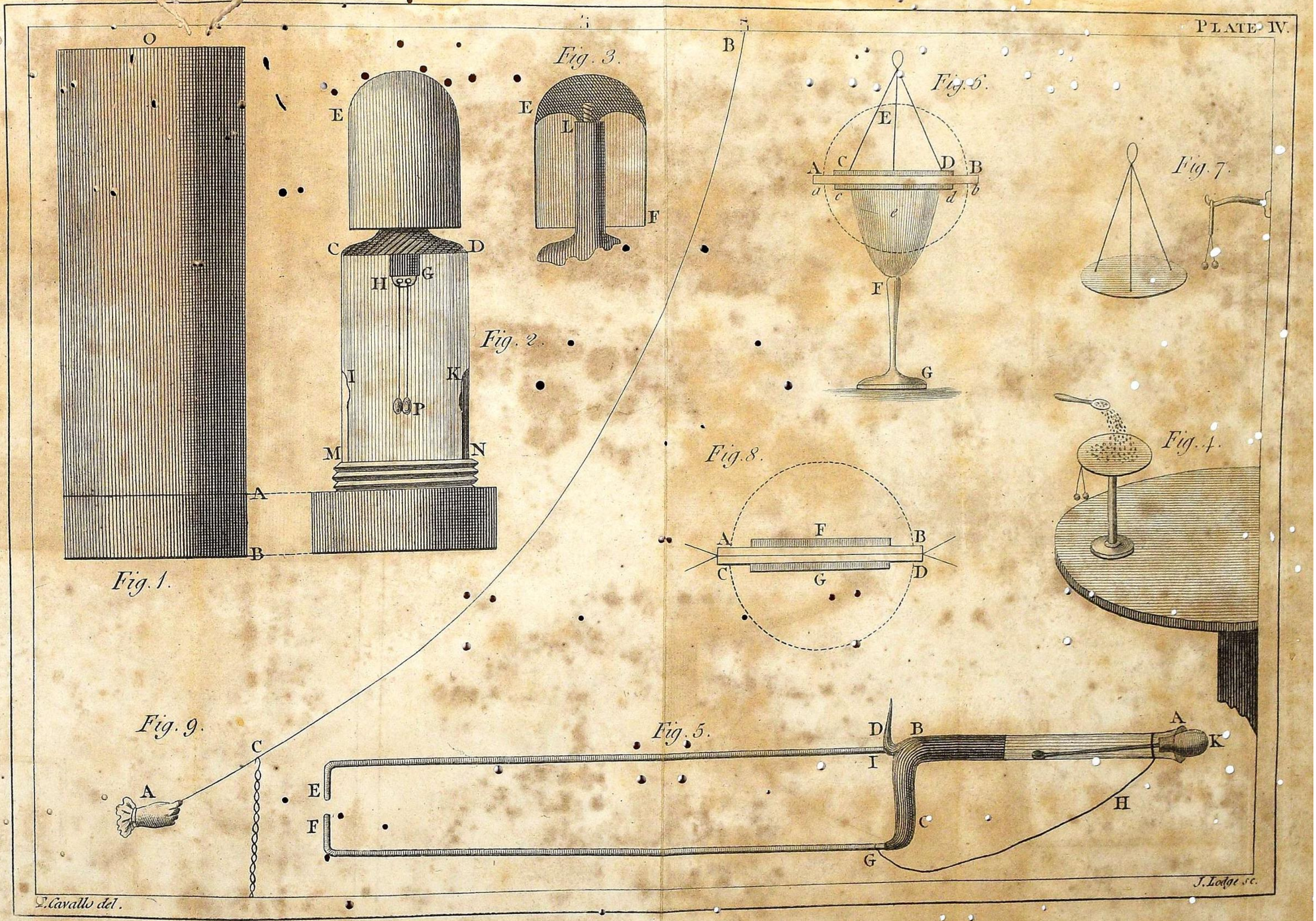


Plate IV.
Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4.
Fig. 5.
Fig. 6.
Fig. 7.
Fig. 8.
Fig. 9.
T. Cavallo del.
J. Lodge sc.